KANGAROOS AND MEN

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THE AUSTRALIAN ZOOLOGIST

VOLUME 16 PART 1

Kangaroos and Men: A symposium of the Royal Zoological Society of New South Wales and held at the Australian Museum, Sydney, on 4th July, 1970.

Inhabits the weſtern ſide of *New Holland,* and has as yet been diſcovered in no other part of the world. It lurks among the graſs: feeds on vegetables: goes entirely on its hind legs, making uſe of the fore feet only for digging, or bringing its food to its mouth. The dung is like that of a deer. It is very timid: at the ſight of men flies from them by amazing leaps, ſpringing over buſhes ſeven or eight feet high; and going progreſſively from rock to rock. It carries its tail quite at right angles with its body when it is in motion; and when it alights often looks back: is much too ſwift for gre-hounds: is very good eating.

It is called by the natives, *Kanguru.*

From Thomas Pennant, 1781,

History of Quadrupeds
2, p. 307.

Pennant's engraving is reproduced on our cover.

KANGAROOS AND MEN

The present issue of *The Australian Zoologist* is devoted exclusively to reports from a symposium entitled "Kangaroos and Men", organised by the Royal Zoological Society of New South Wales and held at the Australian Museum, Sydney, on 4th July 1970. The Council of the Society gratefully acknowledges the generosity of Luv Petfoods Pty. Ltd. in meeting the costs of transport and accommodation of contributors to the symposium and of publication of its proceedings in this *Australian Zoologist*. The organising secretaries were Messrs. Ronald Strahan and Basil Marlow.

Contributors were welcomed by the President of the Society (Mr. J. M. Smail) and the Hon. Sir Percy Spender addressed the well-attended meeting on "A layman's view" of the subject of kangaroos and man.

The whole of the day was occupied by the four sessions:

(1) Kangaroos in Time,
(2) Kangaroos in Space,
(3) Economics of Kangaroos,
and (4) Conservation of Kangaroos.

The papers presented are published in full below.

OPENING

Welcome to Contributors, by J. M. Smail, Ll.B. (President of the Society):

Owing to the shortness of time and because this is essentially a discussion between the contributors, we cannot accept questions or comment from the floor. However such contributions may be passed in writing to the rapporteurs of sessions who will consider them and put them forward at his discretion. The scope of our discussions is broad and we are here to elucidate problems, not to reach decisions or to pass resolutions.

To our knowledge, this is the first symposium devoted to problems of survival of kangaroos. As a Society concerned with conservation we have perhaps been deficient in this but we would not even have been here today without the wholehearted support of Luv Petfoods, whom I must thank both for their courtesy and their farsightedness in meeting the costs of this symposium and the printing of its proceedings. Their generosity in providing funds without any strings attached could well set an example to many other Australian industries.

It is with pleasure that I welcome the contributors to this symposium and invite Sir Percy Spender, well-known as a judge of the International Court and as a man with a great interest in Australian conservation, to make the first contribution to it.

A LAYMAN'S VIEW

By the Hon. Sir Percy Spender, K.C.V.O., K.B.E., K.St.J., B.A., Ll.B., Q.C.

When Mr. Strahan asked me to express a layman's view I thought he must have been looking for somebody who knew little about the subject, in which event I am quite sure that he chose the right person. There came

into my mind an occasion in Canberra—where a long, long time ago I used regularly to see numbers of kangaroos hopping across the road. I expect that there are a few people now who think that Canberra might have been better left to the kangaroos but, that aside, we used to have debates down there on such things as wheat. In one such debate, the Chairman was ignoring the members of the Party to which I belonged and was choosing only members of the Country Party and members of the Labor Party who had country interests. When we protested he looked at us rather benignly and said "Well, I think I am doing the right thing. I am only calling upon those people who know something about the subject". Having said that, I shall try now and express some of my views, such as they are, about the problem which you are called upon to discuss today.

First let me say that I have, as most Australians have, a rather affectionate affinity to the kangaroo. When I have been overseas and seen a kangaroo in a zoological garden, it has given me a nostalgia for home: I think most Australians react in very much the same way. The kangaroo is in some manner representative of the land to which we belong. I am a conservationist—I believe in the protection of the natural life and environment of this country, and I believe very strongly in the protection of the kangaroo. The conservationist can, however, express his views at times too strongly. The other day a group of conservationists went to see the Prime Minister, Mr. Gorton and sought to obtain from the Commonwealth an undertaking to prevent the export of any kangaroo hides from Australia. Mr. Gorton wisely said he had great sympathy for their views but he couldn't go as far as that. And the reason, of course, is that there are other interests apart from those of the conservationists to which some attention must be paid. So I must express my priorities. My over-riding priority is the preservation of the kangaroo and what other interests exist—such as the interests of those who profit from the killing of kangaroos and those who destroy them because they are alleged to be a pest—must rank in a subordinate position so far as I am concerned. That is my own view as a layman. This does not mean, of course, that these interests should in way be unduly affected by measures of conservation.

If one cannot find any convincing reason against cattle and sheep being slaughtered for meat, hides and wool to provide profit for those who seek to use them, then there is no persuasive reason, in my opinion, why the kangaroo should not under proper conditions be available for similar purposes, even indeed to provide food for cats and dogs.

There is, of course, one great distinction between domestic animals and the kangaroos. The herds of cattle and the flocks of sheep increase both in numbers and in quality, because they are conserved for reasons of profit. The kangaroo is not conserved in any way at all except within rather flimsy limits of governmental control. So it seems to me, from a layman's point of view, that it is necessary to determine the proper priorities. Should the animals be primarily available for the purpose of exploitation in terms of profit in the same way as cattle and sheep? Should they, on the other hand, be protected so that they shall never be slaughtered in indiscriminate numbers, so that flocks shall be maintained consistent with the economy of this country? I think one must take a balanced view of these questions and I venture to say that the Symposium will be very profitable if it assists people to get their priorities correct.

Were we to start off and say "The over-riding priority is to allow the export of as many hides as we possibly can in the hope of increasing our export markets", I would be unimpressed. So it is with the argument of producing employment for people or for satisfying a public demand. Those who advance such arguments are usually the very people who have created the demand.

I say to you, as a layman, "Get your priorities right. Is profit more important than the conservation of these unique animals?" I've indicated where I stand. Your task should be to decide, if you can, in your discussions

and in your thinking, how do you preserve them consistent with other reasonable needs. How do you deal with them as a pest? How do you deal with them in terms of use for meat, whether for human consumption overseas in very large quantities—as has been the case at different times—or for pet food or for other manufactures. As a layman, it seems to me that your discussions could usefully proceed in some such order as this.

FIRST SESSION: KANGAROOS IN TIME

CHAIRMAN'S INTRODUCTORY REMARKS

by B. J. MARLOW
Australian Museum, Sydney.

The pouched mammals or marsupials and the placental mammals arose from the same common stock, the Pantotheres, during the Cretaceous period in North America about 120 million years ago. From there, three groups of marsupials migrated into South America and became isolated there due to the submergence of the Isthmus of Panama until the Pleistocene period about one million years ago. These groups were the living American opossums or didelphids, the opossum rats or caenolestids and the extinct borhyaenids which played the role of carnivorous mammals in S. America in the absence of true placental carnivores.

Marsupials also arrived in Australia before it was isolated from the main landmass of Asia in the Cretaceous by means that are not fully understood and these also radiated into three main groups—the flesh eating dasyurids, the bandicoots and the large group of phalangeroid marsupials including the phalangers, wombats and kangaroos.

It will thus be seen that marsupials have radiated mainly in those areas which have been cut off from other parts of the world prior to the main evolution and radiation of placental mammals.

In addition to a wide variety of marsupials, Australia also possesses egg-laying mammals or monotremes which are endemic to the region. The fossil history of these monotremes is unfortunately quite unknown since their remains can be traced back only to the Pleistocene.

Two other groups of terrestrial placentals, bats and rodents, also arrived in Australia during the Tertiary, probably by adventitious means.

Both species of monotremes and the bats of Australia seem to be reasonably secure and are in no danger of extinction at present.

The marsupials and native rodents however give considerable cause for concern. Thirty species of Australian marsupials, embracing representatives of all families, are listed by IUCN in the Red Book of endangered species. It must be admitted that some of these species are very local in their distribution and may still occur in reasonable numbers in certain parts of their range and that some of them would appear always to have been rare and declining in numbers without any interference from man. Many species, however, which were reported to be abundant by early explorers, have now declined alarmingly and this is due directly to human interference with the animals or their environment. This interference may be considered under three headings—direct destruction, the introduction of exotic animals and the destruction of the habitat.

Direct destruction involves pest control operations, sport, and killing for skins or meat. This aspect of interference with populations of animals is that which is most fully under the control of humans. Serious inroads into

populations were made in the earlier days until legislation was brought down to protect the animals concerned. Once this protection had been established, direct killing became of little importance compared with the impact of exotic species and habitat destruction. However the large meat industry which has now developed has renewed the significance of this form of interference.

The introduction of exotic species has probably had considerable impact but its effects are difficult to assess quantitatively. This has involved the introduction of exotic placental predators in the form of foxes, cats and dogs and placental herbivorous competitors in the form of rabbits, sheep and cattle. By and large this situation is now completely out of human control except for our ability, but lack of inclination, to limit the destruction caused by excessive grazing of sheep and cattle. This latter effect is closely related to the third and most serious aspect of the problem which is habitat destruction. This involves the clearing of forest, bushfires, and the degradation of the environment by excessive grazing and trampling, all of which can cause serious erosion and the ultimate formation of desert. The total destruction of the natural habitat cannot help but cause the extinction of all the animals in that area, as for example when eucalyptus forest is replaced with pine trees.

It is quite obvious that a compromise must be made between the attitude of total protection of all natural resources on the one hand and the total exploitation and destruction of them on the other.

This can only be brought about by sound knowledge of the ecology of the situations concerned and rigid control of the utilisation of the resources in question.

Although more and more people are becoming aware of the deleterious effects of human activity in the form of pollution, erosion and general degradation of the environment, the majority still fail to appreciate the total dependence of humanity on the complex ecological system of which it is a part.

This failure to realise man's total dependence on his environment springs in large measure from the arrogant egocentricity of humans who consider that the whole of the natural resources of this planet are specifically for their benefit. This attitude is supported by our philosophy and injunctions from Judaic and Christian writings which advocate—"Be fruitful and multiply, and replenish the earth and subdue it; and have dominion over the fish of the sea, and over the fowl of the air and over every living thing that moveth upon the earth." Such admonishment may be good religious instruction but is dangerously poor ecology.

It is time that humanity took careful stock of the situation and seriously questioned its right ruthlessly to destroy organisms on this planet for short term monetary gain without due regard for posterity.

Unless we learn to appreciate our dependence on the environment which we are destroying with our pollution, exploitation and uncontrolled population expansion, we will find that the extinction which faces numerous examples of biological diversity on this planet may very well encompass our own species.

ON THE FOSSIL EVIDENCE OF THE EVOLUTION OF THE MACROPODIDAE

by W. D. L. RIDE
Western Australian Museum.

(Figures 1-2).

The evolution of the Macropodidae is set against the background of the Australian continental Tertiary and its environments—for the kangaroos and wallabies are a wholly Australian group. They evolved here, they expanded here, and they may well follow the other large marsupials and become extinct here too.

Today both the patterns of changing ecological background within the continent (see Gill 1965, Stirton, Tedford and Woodburne 1967) and of morphological differentiation among its fossil animals are beginning to emerge. Stirton, Woodburne and Plane (1967) have attempted to synthesize the account of the Diprotodontidae and it will not be long before a similar attempt can be made for the Macropodidae.

Since many later and modern Macropodidae are grazing animals their evolution will have to be documented in conjunction with vegetational change and, in particular, with the evolution of grasses which may even have appeared in Australia as early as the Oligocene (Balme 1963).

From the fossils it appears that the tempo of environmental change, as it affected the Macropodidae, was not constant during the Age of Mammals. Firstly something occurred to produce a pre-Pliocene explosive radiation and, secondly, the comparison of fossil and modern species seems to point to the onset of major, and rather sudden reductive changes late in the Pleistocene. The ecological causes of changes in the fossil record are difficult to discover but data are now available which indicate that the late Pleistocene changes are more likely to be due to the activities of the first men who settled in Australia rather than to the climatic fluctuations which were usually postulated as their cause (Merrilees 1968). The instrument of environmental alteration in this case may well have been fire because it is known that the Aboriginal used it both to hunt and to clear country. The proponents of this hypothesis accept the view that naturally caused wild-fire would have occurred in arid Australia, in past ages, but point out that even the fire-resistant, and sometimes pyrophilous, flora of much of Australia can be radically altered by altering regeneration through increasing the frequency of burning as man seems to have done.

The drastic Pleistocene changes are represented in the fossil record of animals by the complete disappearance of all the genera of larger Australian mammals (e.g. *Nototherium, Zygomaturus, Diprotodon, Palorchestes, Phascolonus, Procoptodon, Sthenurus* and *Propleopus*), and leaving a few of the species of *Macropus* as the only large survivors.

No really effective account of the evolution of the Macropodidae against this background has yet been given, although some attempts have been made (e.g. Bensley 1903, Raven and Gregory 1946), and it is even still rather too early to attempt a detailed unravelling of the pedigrees of the modern survivors. This is because those morphological characters of modern kangaroos and wallabies, traditionally used by the palaeontologist, provide us with a complex mass of data which is difficult to interpret as lineages except in the broadest terms. It is almost as if Nature, having once found the set of characters which could be successfully applied to a rather broad range of tasks, within the demands set by herbivorous life, decided to ring the changes on all of them.

Thus, among these typically long-faced grazing and browsing animals (which are often described as the evolutionary equivalents in Australia of the horses, deer, cattle, and antelopes of other lands) one can find some animals with elaborate sectorial premolars and simple molar cusps (e.g. *Propleopus*), some with simpler sectorials and complex molars (e.g. *Macropus*), short-faced kangaroos with broad, and complex, crushing molars and premolars (e.g. *Procoptodon*) and yet other short-faced animals with sectorial premolars and relatively simple molars (e.g. *Dendrolagus*). In recent years the most useful tools in helping the evolutionary biologist to discern the natural groupings of the extant forms has come from the serological and chromosome studies of Kirsch (1967, 1968), Sharman (1961) and Hayman and Martin (1969). While the results of these studies are limited to the clarification of the relationships of modern Macropodidae, an understanding of the way in which these complex and ramifying characters are distributed between the related units, as indicated by these very different kinds of biological data, is enabling the palaeontologist to project backwards into time from these groups, and to allocate fossil taxa to the lineages with a great deal more security. At present A. Bartholomai of the Queensland Museum (*pers. comm.*) is studying the ultrastructure of the dental enamel of extant and fossil Macropodidae in the hope that this will provide data which can be correlated with the sera and other information of the extant forms. Since the characters of the enamel survive fossilization the result of such a study, if it can be correlated meaningfully with other data, promises to be most useful.

The three principal branches of the Macropodidae have long been recognized in classification as the subfamilies which are:

(a) The Potoroinae. The modern survivors of this lineage are called the rat-kangaroos. All have specialized sectorial premolars with a high, shearing, crest; their molars are low-crowned and rather simple.

(b) The Macropodinae. Except for the rat-kangaroos all the surviving kangaroos and wallabies belong to this branch. They are very varied in their dental characters but, with few exceptions (particularly the tree kangaroos, *Dendrolagus*) they are long-faced and have the high-crowned molars to be expected from their grazing habit.

(c) The Sthenurinae. The lineage of short-faced kangaroos has no modern survivors. They had elaborate premolars and a number of functionally related characters in their skulls and teeth which can together be interpreted as specialization for a heavy, browsing, diet.

It is my purpose here to discuss what is known of the early fossil record of the Macropodidae and to suggest how the characters of the fossil Macropodidae can be understood in terms of evolution along these three lines.

THE FOSSIL RECORD

Fossil kangaroos are scarce until the Pliocene—but so too are fossil deposits which have yielded mammals. The accompanying table lists all mammal-containing Tertiary faunas as well as some selected Pleistocene faunas which are relevant to this paper. The numbers below each faunal name represent (from left to right) the numbers of the sub-families, genera, and species of Macropodidae which have been found in each.

The earliest evidence of Macropodidae yet discovered (Stirton, Tedford and Woodburne 1968) is the Ngapakaldi fauna of the Etadunna Formation of possible upper-Oligocene or lower-Miocene age. The fauna accumulated on the bottom of a lake of fluctuating water level with a high carbonaceous content and probably shallow, brackish, water. Conditions were perhaps somewhat similar to those which are found today in the modern coastal lakes of south-eastern South Australia. Noting the presence of pollens of *Nothofagus,* Myrtaceae, and probable Graminae, at the base of the Etadunna Formation, Stirton,

Tedford and Woodburne comment that the environment was probably the forerunner of sclerophyll woodland and savannah. Two forms of Macropodidae occur in the deposit. They have not yet been described but the authors say that one appears to belong to the potoroine genus *Bettongia* (a genus of modern rat kangaroo) while the other is a somewhat strange potoroo-like species (which may not be a potoroo—see discussion of *Dorcopsoides* below).

The possibly more recent (?Miocene) Carl Creek Limestone of Riversleigh Station, of north-western Queensland, and the Kangaroo Well fauna, of an unnamed formation of the southern part of the Northern Territory, reveal the next youngest material of Macropodidae. Nothing is yet known of their characters beyond that the Kangaroo Well specimen has a fairly high-crowned macropodine molar with incipient antero-posterior links between the lophids. In connection with this tooth Stirton, Tedford and Woodburne (1968 p. 9) say that it most closely approximates to that of the smaller macropodids from other late-Oligocene to middle-Miocene faunas which possess potoroo-like mandibles and macropodine teeth. This remark presumably applies both to the Ngapakaldi potoroo-like species and to the Kangaroo Well tooth.

The probable mid-Miocene Kutjamarpu fauna of the Wipajiri Formation in the Tirari Desert east of Lake Eyre also contains a macropodid. The fossils of the Kutjamarpu fauna accumulated in the stream channel, and pond, sediments of the rejuvenated water shed which incised the locally warped sediments of the older Etadunna Formation which contained the Ngapakaldi fauna. Abundant leaves of *Eucalyptus* and other Myrtaceae have led Stirton, Tedford and Woodburne (1968) to suggest that the fauna inhabited a well-watered terrain with at least eucalyptus woodland along the course of the streams. One, as yet undescribed, genus of Macropodinae occurs in the fauna.

The oldest of the Tertiary faunas of which full descriptions of the Macropodidae are available is the Alcoota fauna of the Waite Formation of the Northern Territory (Woodburne 1967). The deposit was probably laid down during the late Miocene in a system of freshwater lakes. The Macropodidae are *Dorcopsoides fossilis* and *Hadronomas puckridgi*.

Dorcopsoides fossilis is one of those forms which must inevitably cause confusion when first described. Of modern Macropodidae it is most like the wallabies of those strange New Guinea genera *Dorcopsis* and *Dorcopsulus;* its sectorial premolars, which are characterized not only by their size, but also by their large number of ridgelets and grooves, together with relatively low-crowned upper molars (but the lower molars are relatively high-crowned and with weak links developed) caused Woodburne to remove all three genera to the Potoroinae.

Subsequent examination of the blood sera of *Dorcopsis* by Kirsch (1968) gives no support to the transfer of *Dorcopsis* to the Potoroinae and it seems that *Dorcopsoides* should be regarded rather as a good primitive macropodine which possessed characters which are retained today by those two curious Papuan genera. The relationship of *Dorcopsoides* with the early Ngapakaldi species has already been suggested by Woodburne (1967 p. 81) who said of it that it may prove to be a "suitable morphological forerunner" of *Dorcopsoides*.

Hadronomas puckridgi also presents a problem of classification which, although not as fundamental as that involving *Dorcopsoides,* is interesting because it involves the time and mode of separation of the Sthenurinae from the Macropodinae. *Hadronomas puckridgi* is undoubtedly a large, relatively short-faced kind of kangaroo but it has not yet developed the highly specialized crushing premolars of either of the main lines of sthenurines nor, despite its rather large sectorial premolar and simple molars is it one of that rather specialized group of macropodines called the protemnodonts, which are so characteristic of the Pliocene and Pleistocene deposits. Woodburne's conclusion that it should be regarded as a possible ancestor to both lineages is the only course which can be taken with the material available. However the presence in the deposit of macropodid third upper incisors, which Woodburne describes as having a

conspicuous vertical rib developed at the antero-lateral corner of the tooth, posterior to which the lateral enamel-covered surface is essentially flat, suggests further possibilities. Such a tooth is in keeping with the morphology of the sthenurine incisor in which this feature has been interpreted (Ride 1959 pp. 54-56) as a symptom correlated with a secondary shortening, of the face and incisor row, in functional reversal from a previously long-faced ancestral condition. The protemnodonts do not have this character of the third incisor. Therefore if this tooth belongs to *Hadronomas* I would interpret it to mean that the genus is already advanced along the path of the Sthenurinae and away from common ancestry with the protemnodonts. If, however, it does not belong to *Hadronomas* there is probably an, as yet undescribed, sthenurine in the deposit. Whichever way this tooth is regarded, it seems that all three major lineages were established by Alcoota times.

Finally by the Pliocene and Pleistocene great diversity had been built up by the kangaroo family. All lineages developed high-crowned molars in some species and some increased attritional efficiency through the development of complex systems of ridges and links between the molar lophs which are functionally reminiscent of similar developments in the Equidae and Bovidae among the grass-eating eutherians. As Stirton, Tedford and Woodburne (1968) have said "One of the most striking aspects of faunal change from Miocene to Pliocene time in interior Australia is the increase in abundance and diversity of macropodine and sthenurine kangaroos with relatively high-crowned cheek teeth. The rise of such grazing kangaroos suggests the spread of grassland, open-country environments in interior Australia . . .". Similar changes occurred at the same time among the Diprotodontidae and are expressed in the high-crowned teeth of *Palorchestes* and *Diprotodon*.

THE HYPOTHETICAL ANCESTOR

In the absence of fossils, the classical method of evolutionary taxonomy provides for the construction of lineages and the prediction of ancestors, and other points of dichotomy along the lineages, by grouping forms from a single horizon in time (usually the present day) according to their common possession of morphological characters and differences. These phenetic distances are then projected back along the time axis and a series of nested sets is produced. This phenogram is then usually clothed with phyletic significance and is smoothed out and expressed graphically as the familiar evolutionary dendrogram. Sooner or later, in the construction of such dendrograms, decisions have to be made as to which characters are primitive, so that by the time the bottom of the tree is reached the primitive characters are gathered together in the hypothetical ancestor. In the case of the Macropodidae the slender information now available from the tree itself makes possible an attempt at this using, as the criterion of primitiveness, the clues provided by *Dorcopsoides* and the trenchant premolars and "macropodine-like" molars attributed to the Kangaroo Well and Ngapakaldi forms.

From these clues it is possible now to postulate an Eocene (or even possibly earlier) ancestor from whose characters the paths taken by the lineages can be projected. To date we have no information from these fossils other than about teeth, but it seems safe to say that this Different Animal will probably have somewhat bandicoot-like hindlegs and possum-like fore feet (not widely different from those of modern *Potorous*). But when it is found, it will probably be recognized by its teeth.

The lower molars of this Different Animal will be almost tribosphenic (see figure 1) like those of ancestral marsupials (and the modern American opossums) but of the cusps the first, the paraconid, will be rather low and pushed back towards the metaconid and protoconid. In its descendants this strange paraconid will later become the "anterior basal cingulum" of the lower molars of most Macropodidae (Ride 1961, Berkovitz 1967). As is the case in the American opossum, the four main cusps (metaconid, protoconid, endoconid and hypoconid) will be transversely related by ridges running down into a

median longitudinal valley. The lower milk-molar (deciduous premolar, dP_4) will be partly molarized and wedge-shaped, very much like that of *Dorcopsoides* with the protoconid and metaconid standing close together; the crest from the paraconid in advance of them forming an antero-posterior shearing crest. The permanent lower premolar (P_4) that will replace the milk-molar, will be a sectorial, probably with three distinct cusps arranged in linear order. The anterior premolar (P_3) will probably be a bicuspid. The incisor will be procumbent; a masteric canal will be developed in functional association with the sectorials and procumbency (see Ride 1959).

The upper molars will have already departed from the primitive marsupial tuberculo-sectorial form by reduction of the row of stylar cusps as separate entities until only stylar cusps a and c have remained as well developed points on crests which will fall away anterobuccally and posterobuccally from the principal anterobuccal cusp (which probably represents stylar cusp b standing close beside the paracone). A well formed hypocone will lie posterior to the protocone and mesial to the metacone; the resultant tooth will be almost rectangular. The milk-molar (dP^4), like that of *Dorcopsoides*, will have an enlarged parastylar shearing crest so that this tooth is, like the lower milk molar, effectively wedge-shaped. Molarisation of the premolars, as is usual in mammals, is more advanced in the upper tooth row than in the lower (see Slaughter 1968). The posterior permanent premolar (P^4) which develops in the dental lamina between dP^4 and P^3 (Berkovitz 1966), will have added a protocone lingual[1] to the posterior cusp of the shearing crest. The anterior premolar (P^3) will be an antero-posteriorly short, probably bicuspid, tooth with cusps arranged in linear order in the same way as its equivalent in the lower jaw. Canines will be present in the interval between the incisors and the premolars. There will be three incisors and it is probable that the first incisor will be the largest.

The teeth which are postulated for this Different Animal can be seen to be not very different from those of *Dorcopsoides*. The lower molars are rather more reminiscent of their tribosphenic ancestry by virtue of their better developed paraconids; but the principal obvious difference will lie in the upper premolars where the sectorial P^4 will be much less elongated and, so, will only replace dP^4 when it erupts. Its characters by comparison in the series M^1 : dP^4 : P^4 : P^3 will show the molarisation gradient quite clearly. Although the occurrence of a molarisation gradient along the cheek teeth of mammals has long been recognised (see Butler 1952) it has not been understood in the transitional area between premolars and molars of Macropodidae—probably because it has been secondarily concealed by a specialised (and superimposed) "sectorial gradient" which is most advanced in the supposedly most primitive of the modern Macropodidae (i.e. the rat kangaroos and, particularly, in *Hypsiprymnodon*).

From the condition of the teeth in the Different Animal, in the evolving Potorinae the major dental emphasis came to lie on the shearing nature of the premolars; they continued to be omnivores but, as opportunists, cut their way through flesh, bones and all, as well as roots and twigs. The molars became more bunoid and the P4 less molarised. In the case of *Bettongia* and *Hypsiprymnodon* both P3 and P4 became highly serrate (the posterior one most elaborate) and in some species the teeth at the posterior end of the molar row became greatly reduced (a similar, but parallel, situation is to be seen in *Burramys* and some caenolestoids, see Ride 1956, 1962). In the case of *Hypsiprymnodon* this secondarily imposed, and specialised "sectorial gradient" even extended into the milk molars where, in dP_4, the metaconid shifted across to lie in linear sequence between the paraconid and protoconid (see Ride 1961, Fig. 2). Members of the potoroine lineage did not all remain small.

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[1] Molarisation of the upper premolar by the addition of a protocone to the postero-lingual corner is usual in mammals (Slaughter 1968), besides which it is the sequence of development of the third cusp in the phalangeroid *Trichosurus* in the molarised dP^4 (Berkovitz 1968).

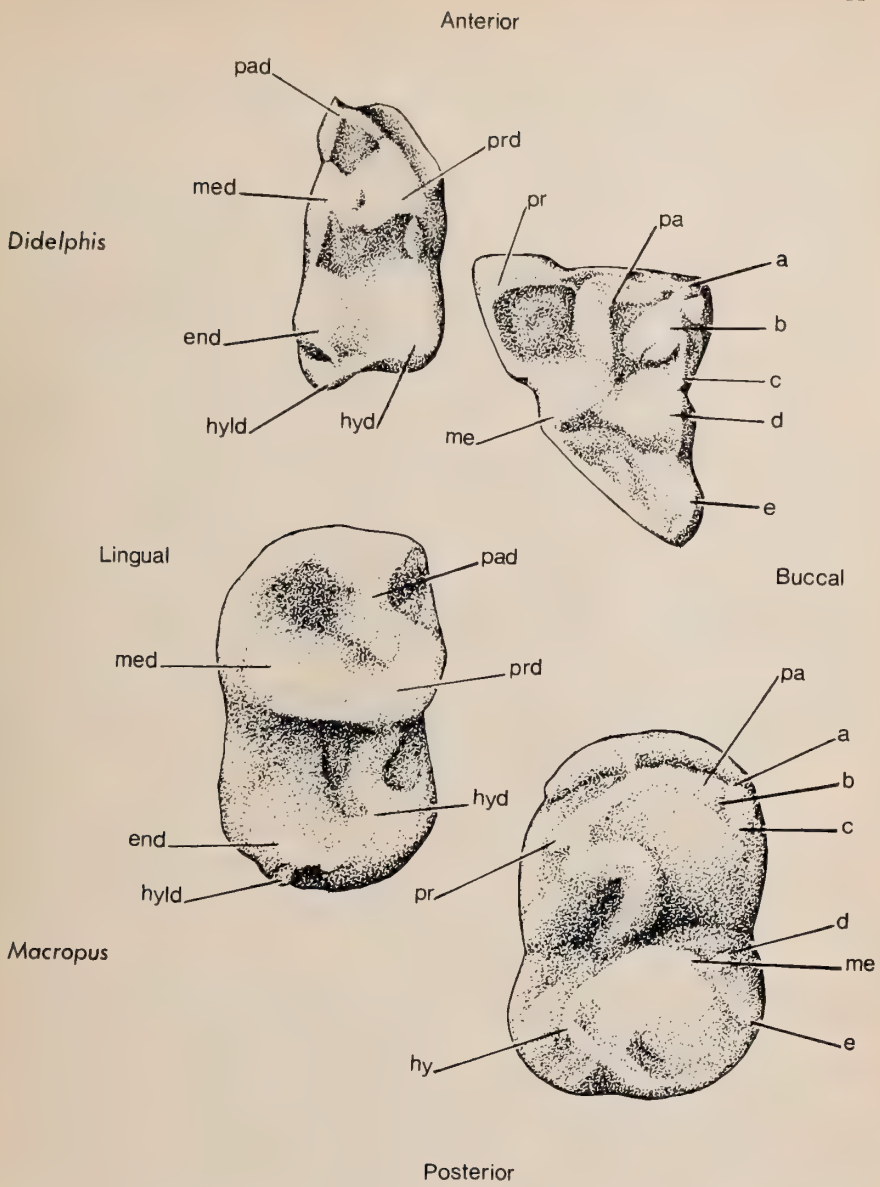

Figure 1.—The molars of a didelphid (*Didelphis*: after Crompton and Hiiemäe. 1969, *Discovery* 5(1):24) compared with *Macropus fuliginosus* (M3 of Western Australian Museum M 3350) to demonstrate suggested cuspal homologies. The molars of the Different Animal will lie between these extremes of tuberculo-sectorial form and lophodonty but with the cristal relationships common to both.

Abbreviations: a, b, c, d, e stylar cusps,
end endoconid, hy hypocone,
hyd hypoconid, hyld hypoconulid,
me metacone, med metaconid,
pa paracone, pad paraconid,
pr protocone, prd protoconid.

The specimen from the Forsyth's Bank Pliocene seems to have been as large as a fair-sized wallaby (see Ride 1964, p. 124) and, by the Pleistocene, *Propleopus* indicates that they reached the size of modern kangaroos (see Woods 1960).

By contrast with the potoroines, the members of the Macropodinae retained emphasis on molar attrition throughout their evolution. In some (like the protemnodonts) the premolars have become specialised secators and molarisation of the upper premolars has proceeded by the development of a second shearing crest lingual and parallel with the original crest of the P^4 of the Different Animal. This crest is a cingulum which extends anteriorly from the protocone. In other lines (e.g. leading to some *Macropus*) the premolars became relatively unimportant as secators and, while becoming reduced, took their place as somewhat molarised teeth in the battery of grinders[2]. When grass-eating became the fashion, the wear produced by the high silica content was counteracted by the development of hypsodonty as well as by the forward movement of the whole tooth row in the ageing animal. The premolars, being grinders like the rest, are pushed forward out of use as the row moves forwards. In other macropodines (such as some wallabies) the premolars continue to be important and, in these the molars may, as they wear out, be pushed out of the tooth row antero-laterally behind them. Other variations, based upon dietary specialization can be discerned in this complex group.

Finally, in the short-faced Sthenurinae (which reached their most extreme form in *Procoptodon*, see Tedford 1966) the premolars also became functionally involved in attritional grinding of heavy (but not necessarily siliceous) material as well. The end-products of this series were that extreme facial shortening took place, the premolars developed complex grinding surfaces, the incisors became less procumbent, the mandibular symphysis became coossified, the masseteric canal became virtually non-functional, and even the incisor tooth row became anteroposteriorly shortened (see Ride 1959).

EXPLOSIVE SUCCESS AND ITS AFTERMATH

Although our knowledge of the fossil deposits is still too poor to say with any certainty when the great explosive radiation of Macropodidae took place it seems probable that the basis upon which it developed was established by Alcoota (probably late-Miocene) times. But there can be no doubt that it reached its peak before the end of the Pleistocene.

Even what little data we have of Pleistocene macropod faunas provide striking comparison with the modern faunas of the same parts of Australia. Thus, in the Eastern Darling Downs, Bartholomai's current research (*pers. comm.*) is revealing that in Macropodinae there were 9 species of *Macropus* using the concept of Calaby 1966, p. 53), 1 *Wallabia*, 1 *Troposodon*, 3 *Protemnodon*, 1 *Thylogale*, 1 *Onychogalea;* of Sthenurinae there were 3 *Procoptodon* and 5 *Sthenurus;* and of Potoroinae 1 *Aepyprymnus* and 1 *Propleopus*. By contrast, in the Warwick district of the eastern Darling Downs today, Kirkpatrick (1966) records in Macropodinae 5 *Macropus*, 1 *Wallabia*, 2 *Thylogale* and 1 *Petrogale* and in Potoroinae 1 *Aepyprymnus* and 1 *Potorous;* there are no Sthenurinae. In south-western Australia the Pleistocene Mammoth Cave fauna reveals (Merrilees 1968) that in the Macropodinae there were 4 species of *Macropus*, 1 *Wallabia*, 1 *Protemnodon* and 1 *Setonix;* in Sthenurinae there were 2 *Sthenurus;* and in Potoroinae there was 1 *Potorous*. In modern times Macropodidae comprised 3 *Macropus*, 1 *Petrogale*, 1 *Setonix;* Sthenurinae were absent; and Potoroinae comprised only 1 *Potorous*. In western Victoria the possibly Pleistocene (or early Recent) Mt. Hamilton fauna (Wakefield 1963) contains of Macropodinae 3 species of *Macropus*, 1 *Thylogale* and 2 *Onychogalea;*

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[2] When molarization extends into the lower premolars the posterobuccal part of the tooth gains a hypoconid.

in Potoroinae 2 *Bettongia,* 1 *Aepyprymnus* and 1 *Potorous.* In Recent times this same area probably held 2 species of *Macropus* and 1 *Thylogale* as well as 1 *Bettongia,* 1 *Aepyprymnus* and 1 *Potorous.*

There are many objections to drawing conclusions and making comparisons from data of this kind because there are so many variables which could be responsible for the observed differences. For example the time-span represented by the deposits of the Eastern Downs probably covers far more than a single faunistic horizon, while the present day fauna of Warwick certainly only contains one. There is probably less error in comparing the Mammoth Cave fauna with that of the present day. But there is no doubt that, even to the most optimistic interpreter, these, and other data (see Merrilees 1968), indicate that a considerable reduction has taken place in the number of large forms in the mammal fauna and that these large animals have not been replaced by any faunistic equivalents unless they be the sheep and cattle which man has recently brought in.

It is the business of the palaeontologist to discover of his chosen group its origin, its growth in diversity, the sudden adaptive explosion which has meant success, and its eventual decline through maladjustment—to its possible ultimate disappearance. The kangaroos are the last of the great Australian marsupials to survive and, if we are not cautious in our employment of the continental environment, we may be called upon to document their end.

How pleasant it would be for the palaeontologist if he could forget this and devote his energies to the light-hearted pursuit of the Different Animal which, according to the *Sing-Song of Old Man Kangaroo,* has long been worthy of pursuit. To remind those who have not read the *Just So Stories* for a long time:

This is the Different Animal dancing at the base of his family tree in the centre of Australia. The breakaways in the background are probably mesozoic and the time is probably Eocene (or could be earlier). (Somewhat modified after Kipling, 1908).

> "Not always was the Kangaroo as now we do behold him, but a Different Animal with four short legs. He was grey and he was woolly, and his pride was inordinate; He danced on an outcrop in the middle of Australia . . . saying 'Make me different from all other animals; make me popular and wonderfully run-after by five this afternoon'."

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EPOCHS	STAGES	TASMANIA	VICTORIA	SOUTH AUST.	WEST. AUST.	N. TERRITORY	QUEENSLAND	NEW GUINEA
		Faunas	Faunas	Faunas	Faunas	Faunas	Faunas	Faunas
PLEIST.	UNSPECIFIED		Mt. Hamilton 2:8:10		[C14 31,000 B.P.] Mammoth Cave 3:6:10		Eastern Darling Downs 3:10:26	
PLIOCENE	KALIMNAN		[K/A 4.35 m.y.] Hamilton 2:6(?7):7 Forsyth's Bank 2:2:2	Palankarinna 1:1:1			Chinchilla 2:5:12	[K/A 5.7 m.y.] Awe [K/A 7.7 m.y.]
	CHELTENHAMIAN		Beaumaris 0					
MIOCENE	MITCHELLIAN							
	BAIRNSDALIAN					Alcoota 2:3(?5):4(?5)		
	BALCOMBIAN			Kutjamarpu 2:3:3		Bullock Creek 0		
	BATESFORDIAN					Kangaroo Well 1:1:1		
	LONGFORDIAN	Wynyard 0					Riversleigh 1:1:1	
OLIGOCENE	JANJUKIAN			Ngapakaldi 1(?2):2:2				

AUSTRALIAN FOSSIL MAMMAL LOCALITIES: prepared mostly from data in Stirton, Tedford and Woodburne (1968). Numbers below faunas represent, from left to right, number of subfamilies, genera, and species of Macropodidae in each.

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THE CURRENT STATUS OF AUSTRALIAN MACROPODIDAE

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SUMMARY

European settlement of Australia has had a profound effect on the status and distribution of the members of the kangaroo family. Of the approximately 45 species, three are almost certainly extinct, and about another dozen have suffered a great decline, or were always rare and localized. The status of the remaining species is satisfactory at the present time although some of these are considerably reduced in range.

The majority of species found in the sparsely-settled tropical north and the eastern and south-eastern forested country still occur in satisfactory numbers. A drastic decline has occurred among the small species of several genera, that were formerly abundant in the lower-rainfall sheep and wheat country of southern Australia. The rabbit and possibly the fox have apparently contributed to the decline in this country. Rock-wallabies (*Petrogale*) have fared better than other small kinds, presumably because their habitat is at least partly inaccessible to stock. Large species have generally suffered least and occasional ones have even improved their status as a result of changes brought about by settlement.

I. INTRODUCTION

The Macropodidae, with about 45 species in Australia including two shared with New Guinea, and a further ten confined to New Guinea and nearby islands, is the largest family of Australo-Papuan marsupials. At the beginning of European settlement at least one kind of kangaroo* and usually several, up to as many as twelve, were found in every part of Australia, except for a few unfavourable areas such as the smaller islands and the higher parts of the south-eastern mountains. Since that time great changes have taken place in the status and distribution of the kangaroos, and they are absent from large areas of closely settled districts.

II. DISTRIBUTION AND STATUS

There are two subfamilies and 16 genera of kangaroos and it is convenient to examine their status under genera.

Subfamily Potoroinae

Hypsiprymnodon. The single species, the musk rat-kangaroo (*H. moschatus*) occurs in tropical rainforest along the coast and slopes of the ranges and tablelands of north-eastern Queensland from near Helenvale, about 15 air miles south of Cooktown (Tate 1952) to some distance south of Ingham, possibly as far as Mt. Spec, about 25 air miles west-north-west of Townsville. Tate, who was familiar with the species in the field and had collected it,

* A century ago it was customary to call all members of the family "kangaroos" when speaking in general terms but nowadays a variety of names are used for individual species, genera or other groups, and there is no general term other than the rather clumsy "macropodids" or its abbreviation "macropods". For reasons of convenience and simplicity I advocate a return to the use of "kangaroos" as a general term embracing all members of the Macropodidae.

"caught a glimpse" of a specimen at Mt. Spec, but Lavery and Johnson (1968) did not find it there "despite particular efforts at collection." Its total range is over 200 miles from north to south and about 40 miles wide at its widest part in the Ravenshoe-Innisfail area. The range of *Hypsiprymnodon* has been affected by clearing of rainforest for agriculture, especially cane-growing and dairying. However, the animal is still observed regularly in a number of localities, and it cannot be considered an endangered species at the present time.

Potorous. It is considered for present purposes that there are two species in the genus. The most widespread is the potoroo (*P. tridactylus*) which occurs from south-eastern Queensland as far west as the Warwick district (Kirkpatrick 1966), through coastal New South Wales to south-western Victoria. It is said that in the early days of settlement it was found in south-eastern South Australia but the evidence for this seems to rest on Thomas's (1888) mention of a skull from the "Murray River, South Australia." It is worth noting that *P. tridactylus* was not found in bone collections from Aboriginal occupational sites on the lower Murray in that State (Wakefield 1964a). Even at the mouth of the Murray the rainfall is no higher than 20 in. per annum, and *P. tridactylus* has not been recorded in historical times at any locality with a rainfall less than 30 in. Finlayson (1935) stated that its former occurrence in south-eastern South Australia was attested by the accounts of settlers but it was apparently uncommon there at the time of settlement. The potoroo is found in Tasmania and the Bass Strait islands. A distinct subspecies (*P. t. gilbertii*) formerly occurred in south-western Australia but it has not been collected for over eighty years and is presumably extinct. Its distribution seems to have been restricted to a limited area in the wetter south-western coastal country and few specimens reached museums before it disappeared.

Until recently the potoroo was believed to be very rare in mainland Australia but it is now known that this was an unduly pessimistic view probably due to lack of observation. In the last few years specimens have been collected or observed at quite a number of places in south-eastern Queensland and coastal New South Wales, some of which are mentioned by Calaby (1966), and it is well distributed in southern Victoria (Seebeck 1968). The potoroo remains widespread and common in much of Tasmania. In Bass Strait it is present but rare on Flinders and King Islands but appears to have gone from Clarke Island which is heavily grazed by stock and rabbits. The potoroo lives in dense shrubby undergrowth and long grass on forest floors and edges and it disappears with the clearing of forest.

The broad-faced rat-kangaroo (*P. platyops*) is apparently extinct. It seems to have occupied a drier habitat than the potoroo and was collected as a living animal in only three localities in south-western Australia. The last specimens were acquired by the National Museum, Victoria, in 1875. It is recorded (*Proc. zool. Soc. London* 1908, p. 783) that a live specimen reached the London zoo on June 9, 1908, and Glauert (1933) goes so far as to state that it came from "the Margaret River". Some years ago I attempted to ascertain the basis of identification of the specimen. Mr. G. B. Stratton, former librarian to the Zoological Society, informed me (in litt., July 19, 1956) that the animal died from enteritis on September 8, 1908 and its remains were apparently not preserved, as might have been expected in view of the known rarity of *P. platyops* and the fact that the species had never been exhibited previously in the zoological gardens. It is highly unlikely that the species occurred in the Margaret River district as its bones have not been identified among the large collections of cave fossils found there (Merrilees 1968). The alleged *P. platyops* was probably a misidentified juvenile quokka (*Setonix brachyurus*). *P. platyops* is also known from bone deposits in caves in south-western Australia (Lundelius 1957), the southern edge of the Nullarbor Plain in Western Australia (Lundelius 1963), Kangaroo Island, South Australia (Finlayson 1938) and Aboriginal occupational deposits on the lower Murray (Wakefield 1964a). It seems obvious that *P. platyops* had declined greatly before European settlement began.

Caloprymnus. The single species, the plains rat-kangaroo (*C. campestris*), was described in 1843 from three specimens from an unknown locality in South Australia. No further definite record of the animal was obtained until 1931 when a specimen was collected on the lower Diamantina in the far north-eastern corner of South Australia. Finlayson (1932) carried out a survey in the area and from personal observations and information supplied by local informants deduced that the species occurred discontinuously over an area in north-eastern South Australia and south-western Queensland, roughly 400 miles from north to south and 150 miles wide. It lived on the stony plains that have a sparse shrub cover and few stunted corkwoods here and there. At the time of Finlayson's survey the country was in good heart following the breaking of a long drought, and in a small part of the area the animal was fairly common. Local observers informed Finlayson that prior to the 1931 irruption the species was extremely rare and by 1935 it had declined almost to its former rarity. It has not been recorded since that date (Finlayson 1961). An old record has it that *Caloprymnus* was common around the head of the Great Australian Bight over 90 years ago (see Finlayson 1932, 1958). It is not supported by a specimen and I regard it as doubtful. Bones of the species have been found in an undated but apparently Recent cave deposit on the southern edge of the Nullarbor Plain, Western Australia (Lundelius 1963) and in late Pleistocene deposits at Lake Menindee, New South Wales (Tedford 1967).

Bettongia. Four species are currently recognized in this genus (Wakefield 1967a). Gaimard's rat-kangaroo (*B. gaimardi*) formerly occurred between the Dividing Range and the coast from south-eastern Queensland to western Victoria, and in Tasmania The mainland subspecies (*B. g. gaimardi*) has not been recorded for more than 60 years and is presumably extinct. The Tasmanian race (*B. g. cuniculus*) can still be found in reasonable numbers in many localities. It has a patchy distribution in woodland and forest and is usually associated with tussock grass and sedgy clearings. A related species, the recently-described Queensland rat-kangaroo (*B. tropica*) is known from six specimens, an old one taken in 1884 in the Rockhampton district and the rest from two localities in the uplands of north Queensland: Mt. Spurgeon, roughly 30 air miles north-west of Cairns, in 1932, and a few miles south of Ravenshoe, in 1922 (Wakefield 1967a).

The brush-tailed rat-kangaroo (*B. penicillata*) has suffered a drastic decline. It was formerly well distributed in south-western Australia, the southern half of South Australia, including St. Francis Island, Nuyts Archipelago (Finlayson 1957), much of New South Wales inland of the Dividing Range, and the extreme north-western corner of Victoria (Wakefield 1966a). Gould (1852) found it "very abundant" in New South Wales in 1839-40. Krefft (1866) found it common near the Murray-Darling junction in 1857; this was apparently the last record in New South Wales, and the only record for Victoria. Wakefield (1967a) has pointed out that the distribution of the animal given by Finlayson (1958) is far too broad. It is known today only in certain parts of south-western Australia south-eastwards from Perth, inland of the heavy forest belt. The habitat of *B. penicillata* in the area is characterized by wandoo eucalypt woodland with a shrub and grassy floor.

Lesueur's rat-kangaroo (*B. lesueur*) has suffered an even more drastic decline. Its former range was greater than that of the preceding species; it occurred over a large part of Western Australia and South Australia, the southern half of the Northern Territory, western New South Wales, and probably south-western Victoria. Tate (1948) mentions three skulls marked "Melbourne" sent to the Museum of Comparative Zoology at Harvard by F. McCoy, but I do not accept this as a valid geographical record. Wakefield (1964b, 1967b) found its remains in caves and Aboriginal midden deposits in the south-western part of the State. Scarlett (1969) provides evidence that in the early days of settlement an animal lived in mound communities on the plains. He attributes the record to the rabbit-bandicoot (*Macrotis lagotis*) but I believe that the brief details given are more applicable to *B. lesueur*. It has not been recorded in New South Wales in this century but survived in

considerable numbers in the desert inland and the south-western Australian woodland until the 1930's (see Finlayson 1958). Today it is known only on Bernier, Dorre, and Barrow Islands off the Western Australian coast. It is common on these islands (Ride 1970).

Aepyprymnus. The rufous rat-kangaroo (*A. rufescens*), the only species in the genus, is widely distributed along the slopes of the Dividing Range and the coastal side of it from about Newcastle to some distance north of Cairns. There seems to be no record of it in southern New South Wales but it was collected as a living animal in northern Victoria over a century ago. There are old specimens in the National Museum, Victoria, from Gunbower and Echuca (Wakefield 1966b) and Violet Town. It was found as far west as the Murrumbidgee-Murray junction (Krefft 1866). Bones of *Aepyprymnus* have been found in cave deposits in south-western Victoria (Wakefield 1964b, 1967b), and Flinders Island, Tasmania (Hope 1969). In the areas where it is found today its habitat is open eucalypt forest or woodland with a grassy floor, and it is quite common in much of its present-day range. The chief industry in this country is beef-cattle grazing and *Aepyprymnus* seems able to coexist satisfactorily with beef cattle (see Calaby 1966).

Subfamily Macropodinae

Dendrolagus. The two Australian species, Bennett's and Lumholtz's tree-kangaroos (*D. bennettianus* and *D. lumholtzi*) live in the rainforests of the ranges and tablelands of north-eastern Queensland. Bennett's tree-kangaroo occurs from near Cooktown to the Daintree River, and Lumholtz's species is found south of here to the Herbert River. Clearing of rainforest, especially on the Atherton Tableland, has considerably decreased the range of the latter species. Both species however still appear to be present in satisfactory numbers.

Lagostrophus. The single species, the banded hare-wallaby (*L. fasciatus*) was once fairly widespread in south-western Australia but has apparently disappeared from the mainland; the last specimen was collected there in 1906. Its habitat was the shrub woodland and shrub-covered sandplain. At the present time it is known only on Bernier and Dorre Islands where it is abundant (Ride 1970). Both Gould (1849a) and Sturt (1849) recorded it in South Australia in the early days of settlement but as no specimens were preserved their statements have generally been discredited. However some support is given to these records by the recent finding of abundant remains in Aboriginal occupational sites on the lower Murray (Wakefield 1964a).

Lagorchestes. Three species of hare-wallabies between them formerly occupied a large part of the grassy woodlands and plains of Australia. A fourth species, *L. asomatus*, is known only from the type skull collected in the 1930's near Lake Mackay on the Northern Territory-Western Australian border (Finlayson 1943). The most widespread species at the present time is the spectacled hare-wallaby (*L. conspicillatus*) of northern Australia. It has been collected recently at both ends of its known range, Barrow Island, Western Australia, where it is common (Ride 1970), and Inkerman, Queensland (Lavery and Johnson 1968). There are a few other recent records in northern Australia but the species seems to be rather uncommon on the mainland. The brown hare-wallaby (*L. leporides*) was formerly very common in parts at least of eastern South Australia and western New South Wales (Gould 1859, Krefft 1866). It has not been seen in New South Wales since about 1890 (Marlow 1958) and in South Australia for an even longer period. There can be little doubt that it is extinct. The western species (*L. hirsutus*) can only be described as very rare. It has disappeared from western South Australia and no specimens have been collected in south-western Australia in this century. It is still found on Bernier and Dorre Islands (Ride 1970) and is still extant but very rare in desert areas north-west of Alice Springs and possibly also at similar latitudes in Western Australia.

Onychogalea. The three species of this genus are distributed in a broadly similar manner to the three better known species of *Lagorchestes*. The northern nail-tailed wallaby (*O. unguifera*) occupies the woodlands and scrubs across northern Australia from the Kimberley Division to the Gulf country of Queensland. It is still widespread and known to be common in several localities in Western Australia and the Northern Territory. The bridled nail-tail (*O. fraenata*) was found in southern Queensland away from the coast, in New South Wales west of the Dividing Range, and in north-western Victoria and, at the beginning of European settlement, was very common (Gould 1849b, Krefft 1866). It has not been seen for many years: the last records were apparently Finlayson's sighting of two animals in the Dawson Valley, Queensland, in the summer of 1928-29 (Finlayson 1931), and a specimen, mentioned by Ride (1970), collected at an unrecorded locality, possibly in central Queensland, in 1937. In New South Wales it was last collected in the Manilla district in 1924 (Marlow 1958). A great decline has been suffered also by the crescent nail-tail (*O. lunata*). It formerly occurred over a large part of southern Western Australia, the south-western part of the Northern Territory, much of South Australia, and probably also the south-western corner of New South Wales. Krefft (1864) recorded it in south-western New South Wales and Wakefield (1966b) apparently accepts the record. It seems to have disappeared from the greater part of this range and is now found rarely only in the ranges in the central part of Australia. The most recent record consisted of the remains of a recently-dead animal, apparently killed by a fox, near the Warburton Range, Western Australia in 1964 (Ride 1970).
Petrogale. In historical times rock-wallabies have occupied the steep rocky hills, cliffs, and rock piles over most of mainland Australia, excluding the greater part of Victoria, south-eastern South Australia and the forested south-western corner of Western Australia. They are found also on a number of islands off the coasts of South and Western Australia, Northern Territory, and Queensland. The highly discontinuous nature of *Petrogale* distribution has resulted in great variation of size and colour, and the taxonomy is confused. Most forms appear to belong to the wide-ranging brush-tailed species (*P. penicillata*) which occurs in all states. It has decreased considerably in numbers and range in eastern Victoria (Wakefield 1961, 1963), south-eastern New South Wales, and south-western Australia and there have been local decreases in central Australia. However it still occurs in good numbers in most of its range. Rock-wallabies are very common in tropical northern Australia. Many forms have been described in this part of Australia but there appear to be two species, the short-eared (*P. brachyotis*) occurring in the Kimberleys and parts of Arnhem Land, and small races of *P. penicillata* in other parts of Arnhem Land. In the ranges south-west of Cooktown Godman's rock-wallaby (*P. godmani*) is found. It may be only another subspecies of *P. penicillata*. Although its range is restricted geographically it has been seen in recent times and is probably not endangered.

The yellow-footed rock-wallaby (*P. xanthopus*) formerly occurred in the Gawler, Andamooka, and Flinders Ranges, and the hills north of Olary, in South Australia (Aitken 1969), and in the ranges in north-western New South Wales and south-western Queensland. It has disappeared from parts of its former range and has decreased greatly in numbers. Most of its range is in sheep country, and at one time large numbers were killed for their beautiful pelts. Its current distribution and status in South Australia can be summarized as follows: uncommon (but definitely not rare) in the Flinders Ranges north of Mambray Creek and in parts of the Gawler Ranges, an outlying colony on Carappee Hill, near Darke Peak on Eyre's Peninsula, rare in the Olary hills (P. F. Aitken, pers. comm.). There is no recent information from Queensland, but colonies are still present in New South Wales north of Broken Hill. Rothschild's rock-wallaby (*P. rothschildi*) is found in the Hamersley Ranges-Pilbara area of north-western Australia, and the purple-necked species (*P. purpureicollis*) occurs in the stony hills and ranges around and south of Mt. Isa in Queensland. The current status of both appears to be satisfactory.

Islands on which populous colonies are still known to exist are as follows: both islands in Pearson group, South Australia (*P. penicillata pearsoni*) (P. F. Aitken, pers. comm.), Mondrain, Wilson, Salisbury, and Combe, Recherche Archipelago (*P. p. hacketti*) (Serventy 1953), Rosemary and Enderby Islands in Dampier Archipelago (*P. rothschildi*) (Ride 1970), Barrow Island (*P. p. lateralis*) (W. D. L. Ride, pers. comm.), Depuch Island, Western Australia (*P. p. lateralis*) (Ride 1964), Magnetic Island, north Queensland (*P. p. inornata*) (Calaby and K. Keith, unpublished), and islands in Sir Edward Pellew Group, Northern Territory (*P. brachyotis*) (Keith 1968). Rock-wallabies occur on other islands in northern Australia but I have no information on their current status.

Peradorcas. The single species, the little rock-wallaby (*P. concinna*), occurs in the northern Kimberleys and the adjacent part of the Northern Territory, and in north-western Arnhem Land. Although its range is seldom visited by zoologists, specimens have been collected in recent years and as the habitat has remained virtually unaltered in historical times there is no reason to suspect that its status has altered.

Thylogale. Three species of the genus are found in eastern Australia. They live in rainforest edges, shrubby parts of eucalypt forests, or dense scrubs. The red-legged pademelon (*T. stigmatica*) ranges from Cape York to south of Newcastle and also occurs in southern New Guinea. The red-necked species (*T. thetis*) occurs from south-eastern Queensland to south of Sydney. Both species have lost ground owing to land clearance for agriculture, dairying, and forestry, but they are still widely distributed over much of their former range and are usually very common where they occur. The red-bellied pademelon (*T. billardieri*) is found over the greater part of Tasmania and is very common in most places. It is also found on some Bass Strait islands but has gone from a number of others (Hope 1969). It formerly occurred in southern Victoria and the south-eastern corner of South Australia but disappeared from the mainland during the last century.

Setonix. The single species, the quokka (*S. brachyurus*) is confined to south-western Australia, where it was very common in coastal districts until the 1930's (White 1952) but then disappeared from much of its range. It is known today in a few swampy areas on the mainland and on Rottnest and Bald Islands where it is still common. Storr (1965) found good evidence that it still occurs on the south coast mainland adjacent to Bald Island although he did not succeed in trapping or sighting any specimens.

Specimens have reached the Western Australian Museum in recent years from the following localities: Ellis Creek near Augusta (1963), Cowaramup (1965), Darling Range about 30 miles south-east of Perth (1968), Two Peoples Bay (1969), and Nannup River (1970) (W. D. L. Ride, *pers. comm.*).

Wallabia. This genus is interpreted as monotypic, containing only the swamp wallaby (*W. bicolor*). It is found from Cape York to south-western Victoria and has the widest "inland" distribution of the eastern forest wallabies, being found as much as 400 miles from the coast in southern Queensland (Kirkpatrick 1970a, Calaby 1970). Its habitat is eucalypt forest and scrubby country. It spends the daytime in dense shrubby gullies and scrub patches but may graze in more open places at night. Clearing of land for agricultural, pastoral, and forestry purposes has led to some decreases in range and abundance but on the whole it still occupies a large part of its historical range and is a common species in much of this range.

Macropus. For reasons given elsewhere this genus is interpreted broadly to include a heterogeneous group of 13 species of kangaroos and wallabies. The tammar (*M. eugenii*) was once found in southern South Australia, south-western Australia from Geraldton south-eastwards probably to the Esperance district and on nine or ten islands off the coasts of South and Western Australia. Although it was common and widespread in coastal scrubs in South Australia prior to 1920 it has now all but disappeared from the South Australian

mainland. At the present time only a small recently-discovered remnant population is known in mallee-broom-bush scrub about eight miles north-east of Cleve on Eyre's Peninsula (P. F. Aitken, pers. comm.). The population on St. Peters Island, Nuyts Archipelago, (*M. e. eugenii*) is extinct and that on Flinders Island, Investigator Group, (*M. e. flindersi*) is reduced to an extremely small remnant unlikely to survive. Clearing for farming and sheep-grazing and occasional scrub fires on Flinders Island gradually reduced the population but several scores were still present up to about 1964 when there was a rapid decline coinciding with a large increase in sheep stocking (P. F. Aitken, *pers. comm.*). A number of colonies are known on the south-western Australian mainland but its range is much broken up because of clearing of the mallee and shrub woodland, etc. that it inhabits, for farming and grazing. The most easterly specimen collected in south-western Australia in recent times was taken at Nyabing (1953) (W. D. L. Ride, *pers. comm.*). The status of the tammar on other islands is satisfactory. The islands are Kangaroo, South Australia; Middle and North Twin Peaks in the Recherche Archipelago, Garden, and East and West Wallabi in Houtman's Abrolhos, Western Australia. The tammar occurred also on North Island, Houtman's Abrolhos but apparently prior to European settlement (Storr 1960). A population on Greenly Island, off the south-western point of Eyre's Peninsula, South Australia, is believed to have originated from an introduction from Kangaroo Island about 1905.

In historical times the parma (*M. parma*) was known in two limited areas of eastern New South Wales, the Illawarra southwards to the Nowra-Sassafras district, and the Dorrigo district where it was last collected in 1932. It inhabited rainforest and the wetter scrubby parts of eucalypt forest. The Illawarra Scrubs were cleared for dairying and agriculture and no specimens from that area have reached museums in this century (Marlow 1958). Today the parma is one of the rarest kangaroos and only one recent record seems to have come to light, Worrell's finding of a specimen at Niagara Park in the Gosford district (Maynes 1970). It should be mentioned that a thriving colony was found in recent years on Kawau Island, New Zealand, the result of an introduction by Sir George Grey in the 1870's (Wodzicki and Flux 1967).

The scrub wallaby (*M. dorsalis*) is found in south-eastern Queensland from about Rockhampton southwards into north-eastern New South Wales. Its shelter habitat is thick scrub such as rainforest edges, thickets of the introduced lantana, and brigalow scrub with thick undergrowth. Clearing for agriculture, grazing, and forestry has affected its range but it is common in much of its range, and is considered a pest in parts of coastal Queensland.

One of the most widely distributed wallabies is the red-necked species (*M. rufogriseus*) which is found from about Rockhampton southwards to south-eastern South Australia. Its range is mostly between the coast and the Dividing Range but it may also be found in timbered areas inland of the Dividing Range. A distinct subspecies occurs in Tasmania and some of the Bass Strait islands. It is a forest and woodland species and is common over the greater part of its range. In many places it is considered to be a pest of agriculture and forest regeneration and some numbers are killed annually. Generations of Tasmanians have killed it in large numbers for its skin, without apparent ill effect on the population. In fact, partial clearing of forest for farming in Tasmania seems to have improved the habitat and it is probably more abundant today than at the beginning of settlement.

The only large wallaby that has apparently become extinct in historical times is the toolache (*M. greyi*). It was confined to south-eastern South Australia and possibly an adjacent strip of Victoria. Its habitat was almost treeless long grass and sedge country, which is also suitable for domestic stock. It was still very common in the early years of the present century when a bonus was paid for its scalp along with those of other kangaroos. The exceptionally beautiful skin was highly valued. Because of its fleetness

of foot and the open terrain coursing it was a popular sport. Competition with stock and human persecution combined to reduce its numbers rapidly, and the last wild ones were recorded in 1924 (Finlayson 1927). Odd individuals survived in captivity for a few years after that date. The nearest relative of the toolache, the brush wallaby (*M. irma*) lives in the drier forest and woodland and sandplain country of south-western Australia from about Geraldton to Esperance. Although its range and numbers have been affected by clearing it is still widely distributed and common in many areas.

The whiptail wallaby (*M. parryi*) is found from Cape York Peninsula to north-eastern New South Wales, mostly on the coastal side of the Dividing Range. Its usual habitat is the drier slopes and hilltops with open eucalypt forest with a grassy floor. It has suffered some decrease in range from clearing but is quite common in most localities.

The agile wallaby (*M. agilis*) has a wide distribution in the Kimberleys, northern part of the Northern Territory, and around the Gulf of Carpentaria and down the east coast of Queensland to just below the Tropic. It also occurs in New Guinea and some islands off northern Australia. The most southerly colonies are on islands in Moreton Bay, south-eastern Queensland, a considerable distance south of its historical distribution on the mainland (Kirkpatrick 1970b). It is largely an open forest wallaby and is very common over the greater part of its range. It is considered to be a pest in pastoral and tropical agricultural areas in many parts of its range.

The remaining species of *Macropus* are the large ones, *the* kangaroos in the popular mind. Their status and distribution have been reviewed recently by Frith and Calaby (1969). The eastern grey kangaroo (*M. giganteus*) occupies suitable habitat in all of Queensland except the most northerly part of Cape York Peninsula, the Gulf Country, and the western border country, almost all of New South Wales and Victoria, and small areas of north-eastern Tasmania. It is a forest and woodland species. The western grey kangaroo (*M. fuliginosus*) is found in similar country from south-western Australia through southern South Australia to western Victoria and New South Wales where it overlaps the range of the eastern species (Kirsch and Poole 1967). A distinctive subspecies lives on Kangaroo Island. Both species have gone from considerable areas of closely settled districts but they are common in many places and their overall status is satisfactory. Their numbers are high in some pastoral districts and they are killed for the meat and hide industries. The Tasmanian forester apparently always had a limited distribution and is now very much reduced in range.

The wallaroos and euros (*M. robustus*) are found in the greater part of mainland Australia, except Victoria and the forested south-west, wherever their habitat—the stony hills and tablelands, and rocky country generally—is found. The euro is also found on Barrow Island, north-western Australia. *M. robustus* has been reduced in numbers in the farming districts of south-western Australia and parts of south-eastern Australia but it is quite common in most of its range. In north-western Australia habitat changes resulting from over-grazing by sheep have favoured the euro and led to a large increase in numbers (Ealey 1967). In the drier inland of some States the euro is killed for the meat industry. Economic developments have so far had little impact on the habitats of the antilopine kangaroo (*M. antilopinus*) of the Kimberleys, northern part of the Northern Territory, and Cape York Peninsula, and the black wallaroo (*M. bernardus*) of the escarpment country of western Arnhem Land. Both species still enjoy their original distribution and status.

Megaleia. The total range of the single species, the red kangaroo (*M. rufa*) is roughly the two million square miles of lightly timbered open plains and grasslands inland of the 10 to 15 in. rainfall isohyets in southern Australia and the 20 in. isohyet in northern Australia. Changes in vegetation due to grazing stock have improved the habitat for it in many parts of its range and it has increased in abundance (Frith 1964, Newsome 1965). In the desert country, a large part of its range, it is quite rare. Its numbers fluctuate

widely as a result of periodical droughts. For many years the red kangaroo has been a mainstay of the hide industry and in recent years the meat industry also.

III. DISCUSSION

Palaeontological and archaeological studies have shown that many Australian Recent mammals had suffered decreases in range prior to European occupation. The warming-up and increasing desiccation since the last Pleistocene glacial period are sufficient to account for this. Recently, however, the idea has been put forward that Aboriginal man caused extensive habitat changes because of his uncontrolled use of fire for hunting purposes and this in turn caused large alterations in distribution and status of animals (Merrilees 1968, Jones 1968). Perhaps both factors were involved. A number of species of mammals that were apparently rare at the beginning of settlement suffered the greater part of their decline in pre-European times. Kangaroos known to be in this category are *Potorous platyops* and *Caloprymnus campestris*.

It was inevitable that European man with his large numbers and superior technology and his need for large areas of land to depasture his stock would have a drastic effect on the countryside and lead to decreases in range of most native species. He knew nothing of the new land and found out too late that some communities, especially the arid and semi-arid ones, were extremely fragile and were degraded probably beyond recovery within a short time. The forested areas, except where the plant cover was completely destroyed, stood up remarkably well to the assaults.

An examination of the distribution and abundance of the kangaroos on a geographical and ecological basis reveals some interesting facts. The status of virtually all species in northern Australia, where settlement has been minimal, is satisfactory, and most species occur in good numbers in the forested parts of eastern and south-eastern Australia. The one exception in northern Australia is *Bettongia tropica*. This was distinguished as a separate species only three years ago and perhaps there has been no incentive for zoologists to look for it. There have been two unaccountable disappearances from the forested south-eastern mainland, *Bettongia g. gaimardi* and *Thylogale billardieri*. Both disappeared a long time ago and before anything was recorded of their detailed distribution or habitat requirements. They may always have been rare and localized. The genus *Bettongia* as a whole seems to have been peculiarly sensitive to change.

The most drastic decline in the kangaroos has occurred among the small species in the lower rainfall sheep and wheat country of the southern half of mainland Australia. In western New South Wales overstocking with sheep up to the 1890's coupled with a severe drought and invasion by the rabbit in the 1880's apparently spelt the end of the small species (*Bettongia, Lagorchestes, Onychogalea*) as none has been recorded since 1890. Most other small mammals had disappeared from western New South Wales by that date. Because of economic factors, agricultural and pastoral development in south-western Australia proceeded at a much slower rate and most small kangaroos survived into this century in the sheep and wheat belt. *Bettongia lesueur* survived there until the 1930's. The rabbit invasion of south-western Australia did not begin until about 1907. Lack of knowledge of mineral deficiencies in sandplain and coastal soils held up development until comparatively recent times, and the abundance of shrubs of the genera *Gastrolobium* and *Oxylobium* which are poisonous to domestic stock had a braking effect on land clearance. It is possible that *Bettongia penicillata* still survives in south-western Australia because considerable areas of woodland containing poison bush were left untouched and ungrazed. In this context it is of interest that the rabbit never invades these unaltered shrub woodlands in strength.

Although the rock-wallabies have disappeared from some areas and their numbers have decreased considerably in the sheep country of the southern half of the continent, they have maintained their status much better than

other kinds of small kangaroos. Their rocky habitat is at least partly inaccessible to sheep and rabbits; however the wallabies must descend to the more level shelves and the bases of the rock piles for most of their food and these places are often grazed by the introduced herbivores. The goat is a much more formidable competitor than the sheep as it can climb virtually anywhere in rock-wallaby habitat. Feral goats are present in some areas inhabited by rock-wallabies, including the Flinders Range (Aitken 1969).

It is difficult to account for the decline of the quokka as its habitat was not under pressure for development and the rabbit had not reached it. Its decline more or less coincided with the invasion of the coast by the fox. The effect, if any, of the fox on native wildlife is one of the great enigmas of wildlife conservation in Australia. There are areas where small mammals apparently disappeared about the time the fox arrived but there are others such as western New South Wales, where the small mammals disappeared before the fox invasion. There are other places again, such as inland south-western Australia, where a good variety of small mammals have coexisted with the fox for many years.

Some species of small kangaroos (*Bettongia lesueur, Lagorchestes hirsutus,* and *Onychogalea lunata*) disappeared or have become very rare in the inland deserts beyond the range of grazing stock. It is possible that the rabbit played a decisive role in these cases. The rabbit is usually rare in the desert areas but periodically, following good seasons, becomes very abundant. *B. lesueur* is the only burrowing kangaroo and its warrens were quickly appropriated by rabbits. Finlayson (1958) believes that *B. lesueur* may have persisted indefinitely at lower population levels, sharing its warrens with the rabbit, but the invasion of the fox was an additional burden with which it could not cope. The known present-day occurrences of *L. hirsutus* are beyond the range of the rabbit and stock.

The importance of islands in the conservation picture is clear. Two species (*B. lesueur* and *Lagostrophus fasciatus*), formerly widely distributed on the mainland, are nowadays known only on islands, and the most abundant populations of the quokka and tammar and possibly the two surviving species of hare-wallabies are on islands. Populous colonies of several forms of rock-wallabies are also found on islands. Fortunately, most islands are uninhabited at least for most of the time. Kangaroos have disappeared from small islands with a long history of farming or grazing, e.g. St. Francis Island (*Bettongia penicillata*), and St. Peters Island and Flinders Island, South Australia (*Macropus eugenii*). Apparently intensive hunting caused the disappearance of *Thylogale billardieri* from a number of islands in Bass Strait (Hope 1969).

The environmental changes brought about by white settlement and the introduction of alien competitors and predators have affected the small kangaroos much more seriously than the large ones. The conservation and rehabilitation, if possible, of the small species present an urgent problem. Surveys are needed to determine more accurately the status and distribution of most species, and even to find some of them. Research into the ecology and habitat requirements of virtually all small species has barely begun.

Until the recent intensification of commercial hunting the large species had everywhere suffered least. Occasional species had actually improved their status as a result of habitat changes caused by domestic stock. None of the large species has as yet become seriously restricted in range; and the only one to become extinct is the toolache, which was an especially vulnerable species confined to a limited area.

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DISCUSSION

Rapporteur: G. B. Sharman, D.Sc., Professor of Biology, Macquarie University.

SHARMAN: It seems to me from listening to the two papers presented by Dr. Ride and Dr. Ratcliffe for Mr. Calaby that we have some enigma here which needs considering. I think, if I understood Dr. Ride correctly, he thought the principal agent of changes by man—and this includes Aboriginal man as well as European man—were those caused by unnatural wild fire. He spoke extensively of the extinction of *Nototherium, Zygomaturus, Palorchestes, Diprotodon,* all of which are very large animals. It seems from listening to Dr. Ratcliffe that it's the small macropodid marsupials which have suffered since European man came into Australia. Since European man came have we had a change in this process of extinction? and I would like to ask Dr. Ride to comment on that if he would, and perhaps he would like to do so now while I read the next question which has been handed in to me.

RIDE: If we can consider the two kinds of man separately, firstly I think we must be very careful in comparing the Pleistocene extinctions with modern, extant, faunas because the fossil record is pretty unsatisfactory and is biased to minimize observed changes. It is relatively easy to make comparison between the records of the large fossil forms with large animals of the modern fauna because they fossilize well. But the comparison is incomplete; it is very difficult to do this with the smaller things, and it is important for us to bear in mind that in Pleistocene fossil deposits, except the relatively modern ones, the record is mostly of the larger forms. It would also be difficult at this stage to give any sort of comprehensive analysis of the smaller forms in terms of the effects of pre-European man and post-European man, but this information is gathering very quickly at the present, particularly as a result of archaeological work, and I would predict that we are going to get a much more complete picture in the next five years. I don't want to be misunderstood about this question of fire; reasonable arguments can be based upon it being the major cause of environmental change in Aboriginal Australia. But I would not say that fire was the major factor, or the only factor, involved in the change brought by European man. I think Calaby's paper has demonstrated this very well.

RATCLIFFE: I don't think I have anything of much value to say. I used to know the late Harry Barnard, a naturalist in Queensland, who went into cattle country about the sixties of last century. He told me that he witnessed a tremendous eclipse of the smaller marsupials in that country and was unable to explain it. I think we can easily explain the disappearance of animals like wallabies in sheep country which is also infested by rabbits. In competition with sheep and rabbits I don't think the small herbivores have a chance.

RICHARDSON: Barry Richardson, of the University of New South Wales Zoology Department, and I am speaking for myself, Gillian Air of the Biochemistry Department and Peter Johnson of the Zoology Department of the University of New South Wales. The marsupial proteins have been used to shed some light on the problems that Dr. Ride mentioned of the difficulty of using morphological characters to decide on the evolution of the kangaroos.

We have been looking at several of them. The first person to really take an active part in this was Dr. Kirsch who is now collecting material in South America to widen his study. We have been looking at two different aspects. Electrophoresis is a special method of analysis which can be used to test new characters. Electrophoresis is a biochemical method that gives data which can be analysed in the normal manner with normal characters. The second method which has been used is amino-acids. This can be analysed in all detail—a new method which has just been introduced. I am happy to say that we have been the first to actively apply it in Australia, and from this we can obtain dates independent of the fossil record and the dichotomies of the different groups. We have done this so far only for two dates: the separation of the eutherian mammals from the marsupials for which we suggest a date of 130,000,000 years, which is the same as has been found from fossil records, and for kangaroos we suggest a date of 40,000,000 years for the separation of the subfamilies of macropods. We are quite interested in Dr. Ride's data, which we have not seen, for his suggestions on that. Now, these give us a method of using data on present-day animals to determine past changes and evolutionary patterns and we hope that they will be very useful. We would like to stress that these are not to be used independently of the older methods: they merely complement the older methods, but we feel that they can be very valuable in the future.

RIDE: The principal problem in deriving dates from these sorts of data is that we must make the assumption that serological change is, in some way, time dependant. Such arguments contain the basic assumption that the rate of serological evolution is constant, but we know from older characters, that we can actually see in the fossil record, that this is probably nonsense: and so, therefore, we believe—or Kirsch and I believe—that there is no justification for implying time dependancy in serological evolution. My reply implies a flat contradiction of the interpretation you have given—my question (without having seen your data or arguments) must be whether there is a basic assumption of time dependancy in your argument.

STRAHAN: I wish to raise a question which I think is pertinent to both papers; what is the status of *Hypsiprymnodon,* the Musk Rat-kangaroo. I don't know whether this is covered in the full text of Mr. Calaby's paper, but I did notice Dr. Ride had little to say about it in his picture of a possible family tree. It is very important, I think, to find out what this species is doing, where it is, and how many of them remain. Can anyone inform me?

RATCLIFFE: There was not time to read the whole of Mr. Calaby's paper, but he states, "The single species, the musk rat-kangaroo . . . cannot be considered an endangered species at the moment".

SHARMAN: May I ask Dr. McDougall of Queensland if he would care to comment on that statement?

McDOUGALL: *Hypsiprymnodon* is quite common in this area but, like all other rare species, if we knew a bit about its habits we would be able to keep it and work on it. It's quite often run over by cars on roads.

Question from Dr. Michael Plane of the Bureau of Mineral Resources.

PLANE: Would Dr. Ride comment on the occurrence unchanged of the genus *Bettongia* from the oldest known fossil fauna, Ngapakaldi, to the present? In other words, would you comment on why one genus has apparently remained unchanged throughout a period of some 35,000,000 years since the beginning of the Miocene?

RIDE: I have not had the good fortune to examine this particular specimen but, whether it is *Bettongia* is not to me the important issue. (I would doubt very much whether it has remained unchanged) but I think the important thing is the fact that the tentative identification of the fossil as *Bettongia* probably depends upon the presence, in the fossil, of large grooved premolars

which could well have existed unchanged. Now, if this is true and the date is right, this could mean that the development of the *Bettongia* and *Hypsiprymnodon* lines occurred a long way before that because these premolars are very highly specialised. On *Hypsiprymnodon,* I would say that it is not the most primitive of the Macropodidae, as is often held, but probably the most specialised of them—it is primitive only in that it possesses a big toe.

SHARMAN: Our discussion has taken us over a fairly wide area with some interesting remarks at the end on these small animals—*Bettongia,* the rat kangaroos and *Hypsiprymnodon,* the musk rat-kangaroo. One of the most interesting and unanswered questions that has come out of the whole discussion is, if we saw a great extinction before the beginning of the Pleistocene and if we are watching now another extinction of the macropodid marsupials, why is it that those which have been the most persecuted by man—Bennett's wallaby in Tasmania, the red kangaroo, the two sorts of grey kangaroo—still seem to be the most prevalent animals? When listening to Dr. Ratcliffe one gets the impression that the big ones are more or less secure, but that the little ones are going out.

RIDE: A point to be considered in the question of persecution is that it may be that most of the forms living in fragile environments are at most times at densities which are too low to make them worth persecuting, but it is the forms that are relatively well buffered and occur in large numbers that get persecuted and can endure it. The red kangaroo seems to have been an animal which has achieved high density as the result of what man has done to the environment, but it may respond differently from the greys which may be better buffered to stand persecution.

SECOND SESSION: KANGAROOS IN SPACE

THE ECOLOGY OF RED KANGAROOS

by A. E. NEWSOME

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(Figures 1-7).

I. INTRODUCTION

The red kangaroo, *Megaleia rufa* (Desmarest), is one of the few surviving giant marsupials. It inhabits the arid lands that coincide approximately with the 15-inch isohyet (Fig. 1). Though its distribution may not have changed much from the ancestral pattern, its numbers certainly have done so. Where once the red kangaroo was so uncommon that early explorers like McDouall Stuart, and Burke and Wills starved, or died as the latter did, it became in this century one of the commonest native mammals. The prosperity of this large herbivore in so capricious an environment is remarkable. Equally remarkable is the prosperity of the euro or hill kangaroo, *Macropus robustus* Gould, and the grey kangaroo, *Macropus giganteus* (Shaw) in the arid and semi-arid country. The increase in numbers followed the advent of domestic stock to their country and were a direct result of it.

Figure 1.—The distribution of red kangaroos and the localities where they have been studied ecologically.

TABLE 1

THE LOCATIONS OF MAJOR STUDIES OF RED KANGAROOS

	New South Wales						Queensland	West Australia		Northern Territory
	Toganmain	Hillston	Ivanhoe	Wilcannia	Tero Creek	Broken Hill	Gilruth Plains (Cunnamulla)	Pilbara (Mundabullangana & Mt. Edgar)	Meekathara	Alice Springs
Abundance	Frith (1964)	Frith (1964)	Frith (1964)	Frith (1964)	Bailey (1967)	—	—	—	—	Newsome (1965a) Newsome *et. al.* (1967)
Distribution	Frith (1964)	—	—	Frith (1964)	Bailey (1967)	—	—	—	Oliver (unpub.)	Newsome (1965b)
Reproduction	Frith & Sharman (1964)	—	—	Frith & Sharman (1964)	Bailey (1967)	—	Frith & Sharman (1964)	Sadleir (1965)	—	Newsome (1964a, b; 1965c; 1966)
Movements	Frith (1964)	—	—	Frith (1964)	Bailey (1967)	—	—	—	Oliver (unpub.)	Newsome (1965b)
Diet	—	—	—	—	Bailey (1967)	—	Griffiths & Barker (1966)	Storr (1968)	Oliver (unpub.)	Chippendale (1962; 1968)
Water needs	—	—	—	—	—	Dawson & Denny (1969a,b)	—	—	Oliver (unpub.)	—

The biology and ecology of the red kangaroo have been studied in considerable detail (Frith 1964; Frith and Sharman 1964; Sharman and Calaby 1964; Sharman and Pilton 1964; Griffiths and Barker 1966; and Bailey 1967 in eastern and southern Australia; Chippendale 1962, 1968; and Newsome 1962, 1964a, b, 1965a, b, c, 1966a, b, and Newsome *et al.* 1967 in Central Australia). The different studies and their localities are recorded in Table 1 and the localities shown in Figure 1. The conclusions from these studies have all been basically similar. The main one is that the cornerstone of the kangaroo's ecology is its food supply.

Results presented here are largely drawn from the studies in central Australia with which I am most familiar. They have the added advantage of covering extensive periods of severe drought and good seasons. Details of other studies can be found in the papers quoted or in their summary in the book *Kangaroos* by Frith and Calaby (1969).

II. BIOLOGICAL NOTES

Red kangaroos mature sexually at ages between about 1.5 and 2 years (Sharman and Calaby 1964), and breed continually in good seasons (Newsome 1962, 1965c; Frith and Sharman 1964). Pregnancy lasts about 5 weeks and pouch-life for the joey around 8 months in good seasons (Sharman and Pilton 1964). Within a few days of giving birth, the female usually comes into oestrus once more, and mates. The resulting embryo does not develop beyond about a 100-cell hollow sphere, the blastocyst, which remains dormant and unimplanted in the uterus until the young in the pouch either leaves naturally after about 8 months, or dies beforehand as happens often during drought (Newsome 1962, 1965c; Frith and Sharman 1964). Normal pregnancy then ensues.

A healthy adult female red kangaroo can therefore rear a maximum of three young every two and half years in good seasons. The production line is quite efficient. At any one time the mother can have a joey-at-heel suckling intermittently on one elongate teat, a pouch-young on a smaller teat, which is producing a different kind of milk from the other (Sharman 1970), and a dormant blastocyst in reserve in one uterus.

Drought interrupts this cycle and has other effects. Females fail to come into oestrus after giving birth because anoestrus sets in towards the end of the pregnancy in the non-pregnant side of the reproductive system (Newsome 1964a). Sexual maturity is retarded about 6 months and young grow more slowly and depend on the mother longer (Newsome 1965c). The growth-curve of the pouch-young onwards is J-shaped. If young die during drought it is just as their growth-rates increase sharply. Apparently the mothers are unable to produce enough milk to provide the increasing demands for nutrition. The ecological effects of drought are outlined later.

III. ECOLOGY

The area where red kangaroos were studied in central Australia covered about 4000 sq. miles. It lay directly north of the MacDonnell Ranges and commenced about 10 miles north of Alice Springs. The countryside includes some of the best habitat for red kangaroos, and some of the worst. Open grassy plains over 2 miles wide flank the ranges. Beyond these lies a band of quite dense mulga (*Acacia aneura*) woodland up to 6 miles through, and beyond these stretches an arid sand-plain dominated by spinifex (*Triodia basedowi* and *T. pungens*), and sparsely treed. Watercourses that run after heavy rain rise in the ranges, drain the open plains, and cut through the woodlands; they support lush green grass on their flood-outs for a long time afterwards.

Artificial waters, both sub-artesian and dams, have been established for stock every 10 miles or so on the open plains and in the mulga woodlands. They are more widely scattered in the unpalatable spinifex country. Cattle graze out from the water points for up to 5 miles around, depending on

the abundance of fodder. They crop the long dry grass of the plains quite severely during long droughts, forcing the perennial species to sprout succulent green shoots from the crown. After good rain falls the grass grows once more to maturity, seeds, and dries off. This cycle bears importantly on the life of the red kangaroo.

TABLE 2

SEASONAL DENSITIES (No./SQ. MILE) ON VARIOUS KINDS OF LAND IN CENTRAL AUSTRALIA

	Drought	Good Seasons	Significant Differences
Open plains (275 sq. miles)	5.3	1.1	large
Mixed open plains and woodland (1113 sq. miles)	2.0	3.1	none
Woodlands (422 sq. miles)	0.3	2.2	large
Spinifex sand-plains (833 sq. miles)	0.2	0.3	none
Totals (2643 sq. miles)	1.5	1.9	none

(a) Numbers and Distribution

Extensive aerial surveys to count kangaroos (Newsome 1965a) have highlighted the importance of these grassy plains and water-courses to them (see Table 2). The kangaroos' distribution changed markedly with the season. During drought they were mostly found in or near the open plains when almost the only available green herbage, though scant, grew there. Over 80% of animals were massed within one mile of these plains (Newsome 1965b); they sheltered in the surrounding woodland by day, and emerged to feed by night on what green herbage they could find in depressions on the open plains. Sometimes mobs numbering hundreds congregated on the green feed. Thus, though the density of kangaroos was estimated at an average of 8.9 per sq. mile on the Mt. Hay plains in October 1961, local densities vastly exceeded that at night. Is it any wonder that graziers were apprehensive, especially since they knew the kangaroos were concentrating on their only green feed?

Within a few weeks of good rain falling, the plains were virtually deserted. The next aerial survey showed that the kangaroos had gone into the mulga woodlands (see Table 2). So much feed had sprung up there that there was no longer any need for kangaroos to become exposed on the open plains when feeding. Instead, they could get both food and shelter in the one place. The spinifex sandplains were always avoided, even when there was a lot of feed there, probably because shelter trees were so few.

These observations indicated that red kangaroos sought above all things short green herbage to feed on, and trees for shade and shelter. Similar conclusions emerged from the studies in New South Wales (Frith 1964; Bailey 1967), though the importance of shade declined towards the Riverina where red kangaroos would rest in the open by day. Such exposure was obligatory on salt-bush plains that had no trees.

(b) Movements

Besides the daily movements from shade to feed, there is a native restlessness about kangaroos. Every now and then some leave apparently perfectly good shade or pasture to hop off some distance, or even out of sight. And there is the tidal movement of the entire population averaging about 2.2 miles between woodland and drought-refuge with change of seasons in central Australia. Thus, red kangaroos do not hold to home-ranges and the pattern of distribution keeps constantly changing.

There is abundant evidence, mostly indirect, of kangaroos moving to storm rains. During severe drought in the Centre, 88 animals were seen along 25 miles of the path of a storm a week after it had passed, whereas only two were seen in 46 miles of similar but drought-stricken country (Newsome 1962). Strong concentrations found here and there during aerial surveys could only be explained by kangaroos following the patchy rain (Newsome 1965a, Newsome *et al.* 1967).

The distance individual kangaroos move in the Centre is not known. The evidence from New South Wales indicates that some kangaroos were relatively sedentary, while others were highly mobile. In a constantly shifting population near the Darling River, Frith (1964) often saw over a period of two months an albino male within an area no more than three miles across. Eight marked kangaroos that he caught and collared moved a net average of about six miles (range: 2 to 14 miles) in periods ranging from 7 to 30 months.

The most extensive movements were those detected by Bailey (1967) though there were some quite localized kangaroos as well. Of 145 kangaroos caught and collared at Tero Creek station in the far north-west of New South Wales, 61 were found later. Forty-one were seen at least once on the station (area: 10 miles x 10 miles) between 6 and 24 months after being marked, some of them several times. One female was sighted 11 times in two years within an area a mile across. Another two animals were known to travel 1.5 miles daily from their feeding ground to water, and return. And another group of animals moved two miles from feed to shelter on four mornings, taking about half an hour for the journey. Bailey also mentions local shifts of kangaroos to areas of storm rains.

These relatively short movements contrast strongly with others later recorded by Bailey in a period of increasingly severe drought which left the pastures thin and dry. All are shown on Fig. 2. The longest movement was 136 miles to the south-west. The next longest was 135 miles across the Darling River to the south-east, the interval between sightings being 14 months. Other long movements were 97, 80, and 60 miles.

The data indicate therefore that the red kangaroo can be quite nomadic though localized in their daily movements for food, water, and shelter. Their longer movements seem to be associated with finding food in drought or, at least, with deserting an area bereft of green herbage.

(c) Reproduction

Though red kangaroos can breed continually in good seasons, females cease to breed and pouch-young die in drought (Newsome 1965c). Large samples of about 150 shot every six weeks for two years made it possible to show that the decline in breeding and the death-rate of pouch-young were directly related to the severity of the drought (see Figs. 3 and 4). Half the females ceased breeding after about 3 to 5 months' drought, and half the pouch-young died after 1.5 to 2.5 months' drought, depending on the time of year and locality. The effect of drought was naturally most severe in summer, especially on pastures overgrazed by stock.

The first change in a drought-stricken population was most marked. Suddenly, many pouches distended through having carried half-grown young were found empty with the elongated teats dry. With the cessation of lactation,

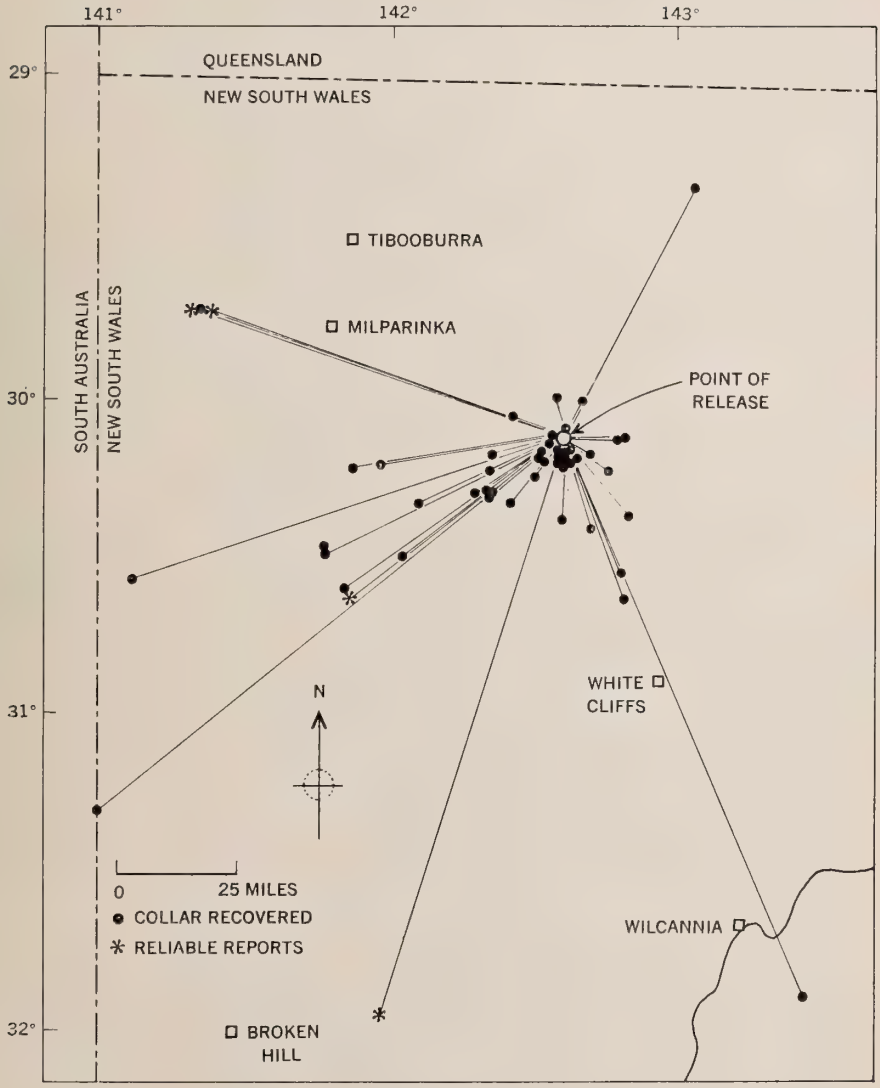

Figure 2.—Dispersal of red kangaroos from Tero Creek during drought (from Bailey 1967).

the previously dormant blastocysts had recommenced development, and so many females were pregnant. Later, many females were found to be anoestrous, with no pouch-young and small pouches. They had ceased all reproductive activity. Surprisingly, other anoestrous females were found that were still suckling (Newsome 1964a) and some of them managed to suckle their young right through droughts (Newsome 1964b). However, if a drought lasted 8 months, all young died. The worst drought witnessed during the 5-year study lasted 9 months; no joeys-at-heel could be found towards its end or for some time afterwards.

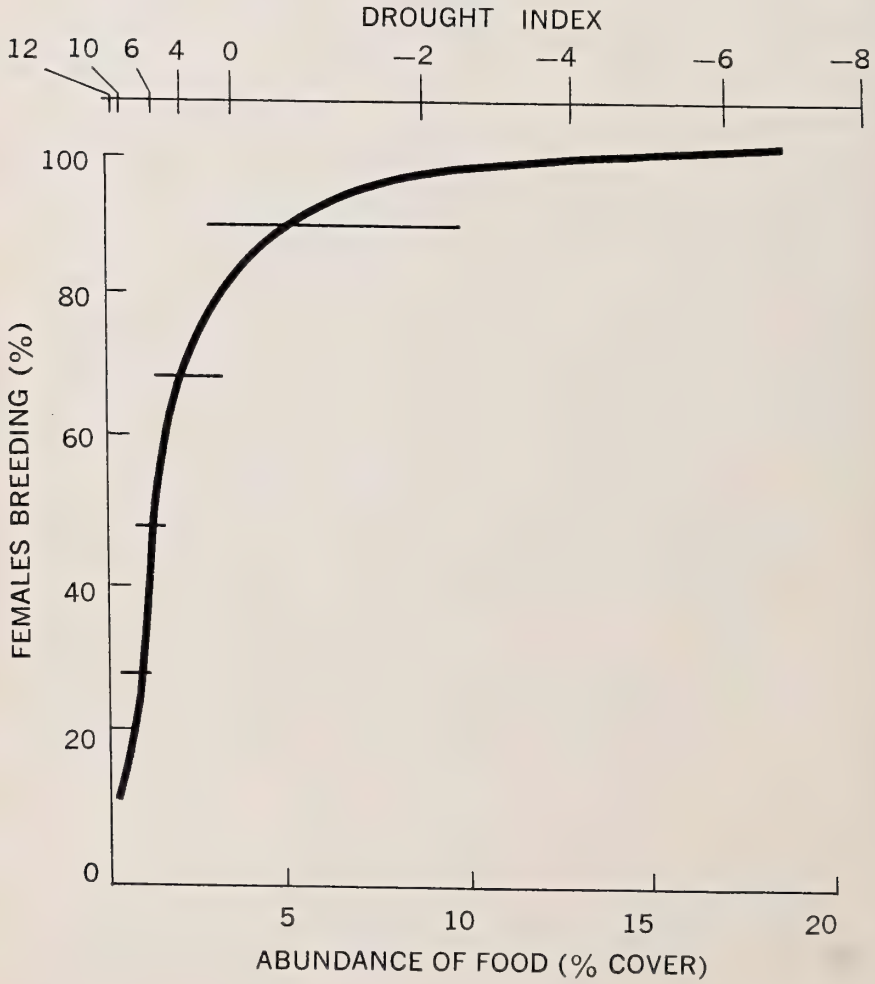

Figure 3.—The relationship between breeding and food supply in central Australia.

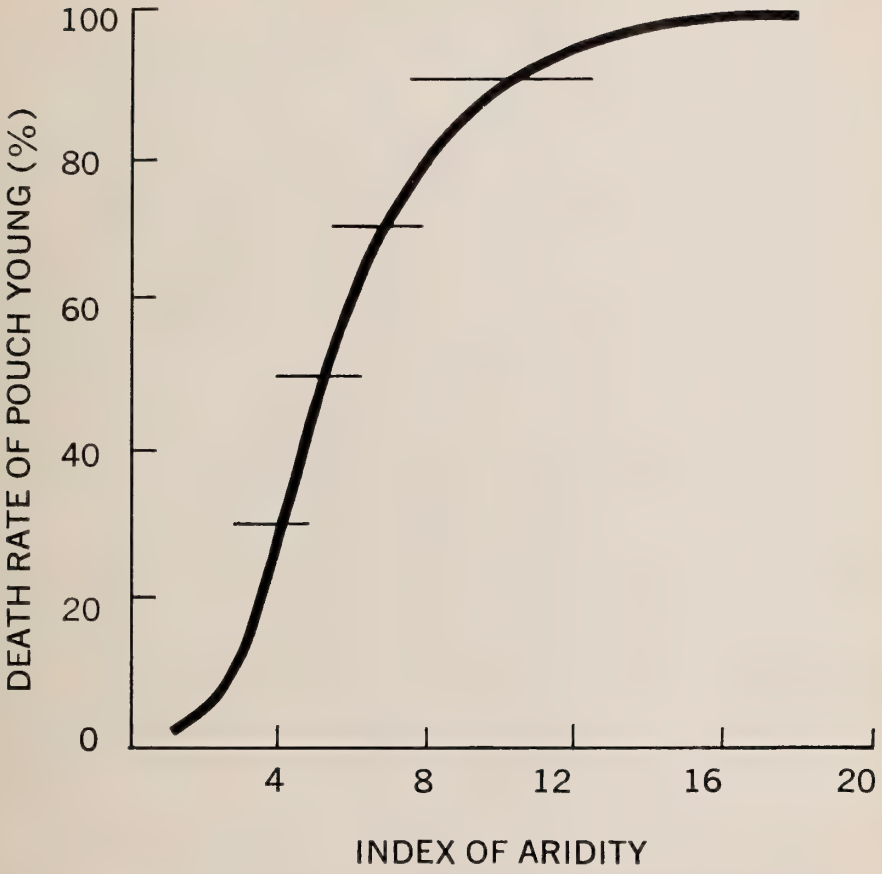

Figure 4.—Death-rate of pouch-young during drought in central Australia.

When it rained and green herbage was once more abundant, all anoestrous animals returned to breeding condition, including those still lactating (Newsome 1964b). About one third of pouch-young found surviving droughts were suckled by anoestrous females. So the contribution of these females to population recovery was considerable. Despite these adaptations to offset drought effects, droughts are nonetheless long enough and frequent enough for large gaps to appear in the age-structures of the adult population.

The breeding rate of adult females has been shown to be linked to the availability of green herbage, which in turn is linked (see Fig. 3) to the severity of drought (Newsome 1966b). The survival rate of pouch-young is almost certainly governed by the same resource as peaks in the numbers of joeys-at-heel seen on the study-area in central Australia were preceded by long periods favouring growth of pastures, the sizes of the peaks being correlated with the length of these periods (Newsome 1965c).

(d) Diet

With so much of the kangaroo's biology dependent on the food supply, and with so much of its status as a pest dependent on claims that it competes with domestic stock, what exactly, and how much does the red kangaroo eat? Of all aspects of the animal's ecology, this has proved the most intractable for a number of reasons. Plants are digested differentially in the stomach making estimates of what was eaten unreliable. More importantly, only the kangaroo knows what it wants to eat, and so it is hard to assess, realistically, what is available to it. Despite these drawbacks a general pattern emerges from the four published analyses (see Table 1) of the red kangaroo's diet, though we cannot place complete reliance on the compositions of diets as calculated. One firm conclusion is that red kangaroos prefer to eat mainly green grass and do not directly compete with stock for food at all times.

Chippendale's (1962) preliminary comparison of the stomach contents of 90 cattle and 56 kangaroos in central Australia showed that cattle ate a much wider selection of plants than kangaroos, especially shrubs and trees (top-feed). For example, mulga was browsed heavily in drought; mature stands around waters are usually "hedged off" as high as cattle can reach. Kangaroos ate mulga rarely.

In a later detailed study of red kangaroos' diet, the importance of grasses was highlighted, especially one species, *Eragrostis setifolia,* during drought (Chippendale 1968). The study was conducted during good seasons and bad on one of the kangaroos' important drought-refuges, the Burt Plain, 30 miles north of Alice Springs. Only one major kind of country is absent on the Burt Plain. This is spinifex sand-plain, which the aerial surveys showed was not important to kangaroos anyhow (see above). The others, open grassy plains, flood-plains and flood-outs of creeks, and mulga woodlands are quite close together there.

Chippendale shot samples of four to 14 but mostly 10 animals almost monthly for two years, making a total of 189 kangaroos examined. The results of microscopic examination of stomach contents, which contained mostly green herbage, have been compressed into Table 3 to show the dominant plants grazed in different seasons. There is no doubt that green grass predominated, particularly *E. setifolia* during drought. Shrubs and trees were rarely eaten. After good rains, perennial dicotyledons, especially *Portulaca oleracea,* and *Helipterum floribundum,* became abundant and were eaten.

The reliance on *Eragrostis setifolia* is due to its dominance in gil-gais and other depressions on the plains and in the flood-outs. Water runs into these hollows after rain so that green herbage lasts longer there than elsewhere. Grazing keeps this perennial grass green also. The link between red kangaroos and gil-gais is so close that Chippendale has suggested that there may be an inter-dependence between the kangaroos and *Eragrostis,* the one presumably supplying fertiliser and the other nutrition. On the other hand, graziers often claim that kangaroos foul pastures. Certainly their faeces pile up in gil-gais after rain, but it has not been demonstrated whether this benefits or harms the plants there.

Griffiths and Barker (1966) examined the diets of red and grey kangaroos and sheep running together on the one paddock near Cunnamulla in western Queensland. Forty-six red kangaroos and 101 sheep were shot for their stomach contents throughout a year from January 1963 which was a good one for graziers, the rainfall being average for the district (15 ins.). Only during the last few months did pastures dry off, but fodder was never in short supply.

There were many similarities in the diets of these three beasts. Red kangaroos ate the same proportions of grass and dicotyledons as sheep, but showed different preferences for the actual species eaten. Table 4 shows, for example, that sheep ate more *Amphipogon* and browse than red kangaroos, and red kangaroos more *Themeda, Kochia* and *Portulaca* than sheep. The authors concluded that there were sufficient differences in the diets of these

TABLE 3

DIET* OF RED KANGAROOS IN CENTRAL AUSTRALIA (% VOLUME IN THE STOMACH)

Plants	Drought (n = 135)	After Rain (n = 54)
Grasses		
Eragrostis setifolia	53.7	24.3
Other perennials	22.0	55.6
Annuals	14.5	18.3
Forbs	8.2	1.3
Trees	1.6	0.5

* Calculated from Chippendale (1968)

TABLE 4

THE DIETS* OF SHEEP AND RED KANGAROOS NEAR CUNNAMULLA, QLD., IN A GOOD YEAR (% VOLUME IN THE STOMACH)

Plant	Red Kangaroos (n = 46)	Sheep (n = 101)
Grasses		
Amphipogon caricinus	3.3	15.3
Aristida spp.	4.8	3.2
Triodia mitchelli	7.9	10.2
Themeda australis	5.4	0.7
Other grasses	32.8	17.1
Forbs and browse		
Kochia tomentosa	13.4	6.8
Portulaca oleracea	15.9	4.8
Malvaceae	0.8	7.1
Acacia aneura	0.1	8.1
Eremophila longifolia	1.4	11.3
Others	9.3	13.6
Unidentified	4.9	1.8

* Calculated from Griffiths and Barker (1966).

three animals for them to form an eco-system with their environment. They showed also that the idea that kangaroos eat more than a sheep was a fallacy.

Storr (1968) studied the diets of a similar trio of species, the red kangaroo, the euro, and sheep on Mundabullangana station near the seaboard of the Pilbara District in the dry north-west of Western Australia. His method was to identify plant particles in the dung of these animals. The climate, though dry, is monsoonal and so the annual rainfall, which averages 13.7 in., falls largely between January and May. Like Griffiths and Barker's study, that of Storr coincided with a good year for graziers. In fact, 21.8 in. fell in January, February and March; so perhaps only the results from the sample in November may have given an indication of the diet during drought.

Table 5 shows that sheep and red kangaroos had largely overlapping diets in the early half of the year when food was abundant for all. The only real difference was that sheep ate more non-grasses (mostly herbs and some browse) than kangaroos. In November, when the annual grasses had disappeared, red kangaroos ate more *Aristida* spp. than sheep which had turned even more than before to the forbs and browse for food. The demands of both species on the introduced buffel and birdwood grasses, *Cenchrus* spp., was considerable, and about equal.

Bailey (1967) examined the diet of 488 red kangaroos at Tero Creek in the north-west corner of New South Wales during severe drought, some of it very severe. Only a little rain fell during the study, 5.87 in. in 1964 and a mere 1.78 in. in 1965 (mean for the region = 10 in.!). The stomach contents were examined microscopically. Grasses again predominated comprising around 60% of the volume of the diet. The species favoured most were the perennial *Enneapogon avenaceus*, and "button grass", *Dactyloctenium radulans*,

TABLE 5

THE DIETS* OF SHEEP AND RED KANGAROOS AT MUNDABULLANGANA, W.A. (% AREA IN FAECES)

Plants	Food Relatively Abundant (Feb., May and Aug.)		Food Dwindling (Nov.)	
	Red Kangaroos (n = 157)	Sheep	Red Kangaroos (n = 86)	Sheep
Perennial grasses				
Aristida spp.	7.4	6.5	29.0	1.0
Cenchrus spp.	34.6	33.0	34.0	37.0
Chrysopogon latifolius	7.6	5.6	12.0	15.0
Triodia (3 spp.)	13.2	11.6	4.0	6.0
Eragrostris spp.	7.0	3.6	3.0	1.0
Eriachne spp.	5.0	3.6	1.0	3.0
Annual grasses	12.2	8.5	2.0	0.0
Dicotyledons	13.0	27.6	15.0	37.0

* Calculated from Storr (1968).

an annual that becomes abundant just after rain (see Table 6). Chenopods, mostly *Bassia* spp., were the dicotyledons mostly eaten, especially during drought.

In strong contrast with the results of the other studies of diet where kangaroos ate mostly green herbage, many stomachs contained only a trace of any green material at all. Much of the rest of the stomach contents could not be identified, 20% in periods when there had been some rain, and almost double that during drought. Bailey thought this fodder must have been dried-out stubble of *Enneapogon,* which was almost the only herbage available. Certainly, the red kangaroos were eating it.

All four studies of diet support the concept derived from studies of numbers and distribution that red kangaroos prefer a diet of green grass. Bailey alone found kangaroos living on dry grass. Though they seemed healthy enough, most of these animals had ceased to breed, and a good many animals had moved away from the drought-stricken area (see Fig. 2 above). It is not known why some animals stayed and some left, but it seems certain that those living on dry feed alone would have been steadily losing nitrogen from their tissues. McIntosh (1966) demonstrated that kangaroos on an experimental diet low in nitrogen (0.5%) were in negative nitrogen balance, and Bailey (1967) found only 0.45% nitrogen in the dry *Enneapogon* stubble at Tero Creek.

In general, the diets of red kangaroos and stock were found to overlap. Although the studies largely coincided with good seasons when there was an abundance for all, there was an indication that diets diverged during drought; kangaroos concentrated more on grass, and stock turned more to forbs and browse. It is possible, however, that stock were forced to change their diet during drought because the kangaroos had grazed the scant remaining grasses beyond their reach. This aspect of competition for food has never been studied; graziers believe it to be important.

TABLE 6

DIET* OF RED KANGAROOS AT TERO CREEK, N.S.W.
(% VOLUME IN STOMACHS)

Plants	Period with some Rain (n = 200)	Period of Drought (n = 288)
Grasses		
Enneapogon avenaceus	22.5	6.9
Dactyloctenium radulans	6.0	1.0
Others	11.7	13.8
Unidentified dry grass (probably *Enneapogon*)	20.0	38.6
Forbs		
Chenopodiaceae (mostly *Bassia* spp.)	15.9	23.1
Others	23.9	16.6

* Calculated from Bailey (1967).

(e) The Impact of Stock on the Red Kangaroo

One impact is obvious. There are now a multitude of artificial watering places across the dry inland plains that have removed any shortage of water for the red kangaroo. But there is another, less obvious interaction that also benefits the kangaroos. Stock graze down the long dry grass that kangaroos prefer not to eat, causing soft green shoots to sprout from the crown. Huge areas of satisfactory grazing have therefore been created for kangaroos. Clear evidence for this was obtained in central Australia. On about half of an open grassy plain, near a sub-artesian bore, the grass (mostly *Eragrostis setifolia*) was cropped short and green except inside a quarter mile square holding paddock that had been kept closed to cattle. There the grass was tall and dry. The paddock was surrounded by a standard three-strand cattle fence that was no barrier to free movement of red kangaroos in or out of the paddock.

Red kangaroos were counted on the grazed and ungrazed areas on five nights in 1963; only one out of 276 kangaroos seen was on the ungrazed portion. This evidence helped explain why almost 80% of the 4,500 kangaroos estimated to be on the study-area during drought in 1961 lay close to the grassy plains between 1 and 5 miles out from water (Newsome 1965b). Closer in, most of the pastures had been destroyed by cattle while farther out they had hardly been touched. Cattle had created a "marsupial lawn" on the intervening land by their grazing, thus providing much more drought-fodder for kangaroos than would have been there otherwise.

Stock have similarly ameliorated the red kangaroo's environment elsewhere in Australia through alteration of the composition of the pastures as well as by chewing them down. The once dominant saltbush (*Atriplex* spp.) on the plains of south-western New South Wales and inland South Australia has been eaten out over large areas to be replaced by more palatable grasses, mostly *Danthonia* and *Stipa* spp. These changes have greatly increased drought-refuges for red kangaroos whose numbers have increased throughout inland Australia. I have attempted to represent this increase diagrammatically in Fig. 5.

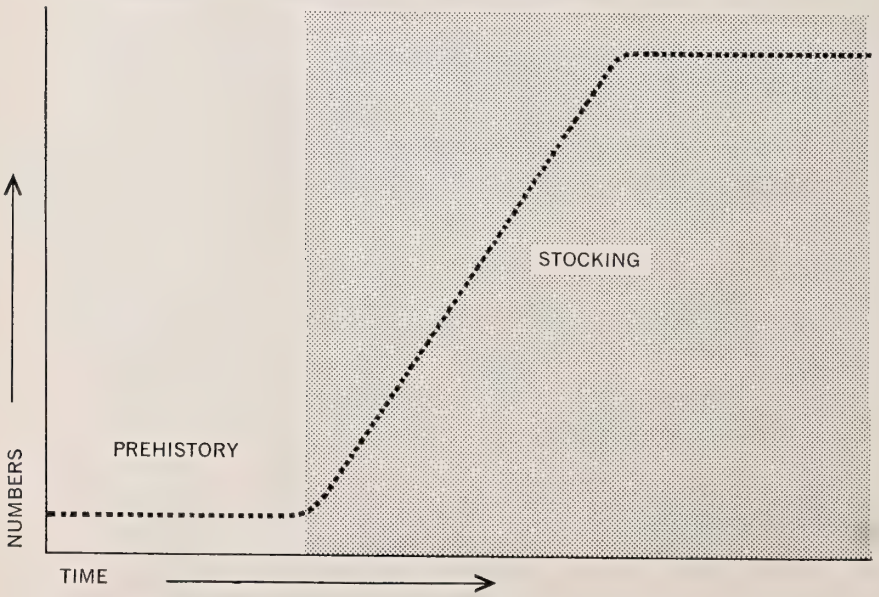

Figure 5.—Diagrammatic representation of the great increase in red kangaroos due to changes in the habitat after livestock were introduced.

(f) Predation

Natural predation by eagles (*Aquila audax*) and dingoes (*Canis familiaris dingo*) was unlikely to have ever been great. Here and there Aborigines may have killed many kangaroos for food, but social rituals prevented excesses. Only since the advent of white man has predation become really important. In the past decade it has been so devastatingly efficient that there has been great public outcry. Just how vulnerable kangaroos are to guns was shown by the operation of two kangaroo-shooters in central Australia during six months of complete drought in 1961.

Figure 6 shows that red kangaroos came back to the open plains to number 10.3 per mile of transect as the country began to dry out after April rains. Shooting then began for winter furs and lasted till September when furs were no longer worth gathering. The two shooters killed about 1,500 red kangaroos in that time reducing the population by about two-thirds to 3.5 per mile. The remainder survived mostly in places unknown to the shooters. Had shooting been for the game-meat trade as well, there was no reason why kangaroos could have been reduced to extreme rarity throughout the drought-refuge for there was just nowhere else for them to go. Once good rain fell in January the kangaroos went back to the safety of the dense mulga woodlands (Newsome 1965a), hence the low count on the plains in 1962.

Thus, kangaroos are extremely vulnerable in central Australia during drought; the dense expanse of mulga woodland protects them after rain. Elsewhere, the distribution of woodlands and open plains is more mixed. For this reason, red kangaroos are vulnerable to persistent shooting over most of Australia at almost any time which is why shooters reduced the once numerous herds of kangaroos to rarity and even local extinction in the past

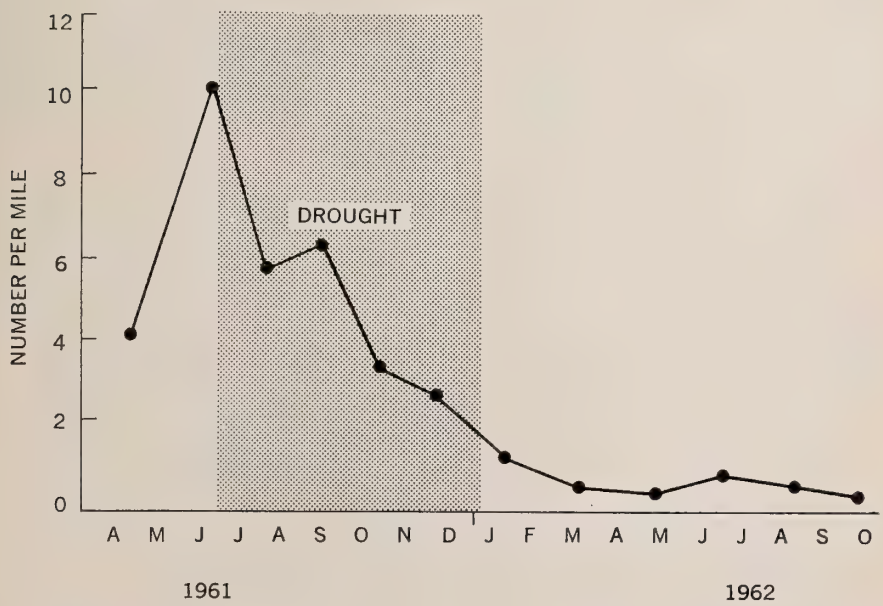

Figure 6.—The decline in mean numbers of red kangaroos seen per mile along a 100-mile transect on open plains in central Australia due to two kangaroo shooters operating during drought.

decade. It was this intense slaughter that brought about the public outcry. The kangaroo's vulnerability is diagrammatically illustrated in Figure 7.

IV. TO HARVEST OR NOT

The controversy over shooting kangaroos is a three-cornered affair. Some people regard red kangaroos as a pest in need of control; some see them as unique native marsupials demanding conservation and are sickened by their callous slaughter; and some regard them as a resource that should be harvested. People are not divided into neat camps over the controversy. Many, like myself, are concerned on all three counts. For simplicity, however, each issue is discussed in turn.

Figure 7.—The vulnerability of red kangaroos to shooters depends on the pattern of distribution of woodlands and open plains in inland Australia.

(a) Status as a Pest

There are times when huge numbers of red kangaroos flock onto small areas. They must consume a great deal of grass. The two largest mobs I saw in central Australia, for example, numbered about 1,500 and 500 and lesser groups of from 50 to 200 were common in drought. At night, up to 15 and even 20 animals would gather to graze at the one small gil-gai. Is it any wonder that the graziers become apprehensive about the benefits of having their impoverished stock share what scant pastures there are with kangaroos during drought? The graziers have, after all, the grazing rights to the leases, and therefore a legitimate complaint. They can claim also broken and damaged fences and the hazards of driving at night where kangaroos are prevalent.

The degree of competition between stock and kangaroos for food is just not known for the crucial season, drought. The advantage to the grazier of reducing large herds of kangaroos cannot therefore be costed, though it is extremely doubtful that for every kangaroo less a sheep could be grazed, because their diets do have differences. But the grazier reasons that, if it is necessary to lighten the stock carried in drought, so too should the load of kangaroos be lightened.

No reasonable man can deny a grazier the right to protect his interests if kangaroos infest his run. As a group, graziers would be the last people to wish the kangaroo extinct and quite a few refuse to have them shot at all. Most are only too glad to see kangaroos on their land but, understandably, not in numbers that threaten their livelihood.

(b) Status for Conservation

On the other hand, native fauna is the property of the Crown and is protected by it. Native animals have a right to live, which means for red kangaroos the right to co-exist on the same land as stock. This is the substance of the conflict.

It is just not true that red kangaroos, despite the shooting, are in danger of extinction at present. There may be local extinction due to drought or shooting, but not extinction Australia-wide. This is no invitation to lower conservation's guard, it is just that there are smaller, less conspicuous relatives of the red kangaroos, plus other distinctive but secretive marsupials, in far graver danger of extinction. Gross or subtle man-made changes to their habitats have left them no refuge, as pointed out by Calaby in this Symposium. Those creatures deserve some of the public sympathy now afforded the kangaroos which are much more numerous now than ancestrally (see above) thanks to abundant artificial waters and to live-stock acting as lawn-mowers.

Let us examine, however, the possible outcome of giving the red kangaroo complete protection, something it has never had, not even ancestrally. There are enough apt examples in the literature to warn us of the prospects. The elephants of Africa, once hunted for food by tribesmen, later became heavily exploited for the ivory trade and became quite rare and even locally extinct. Nature reserves were established in which they were completely protected. Peinaar (1969) graphically describes how elephants were thought extinct when the Sabie Game Reserve (now part of Kruger National Park) was proclaimed in 1898. A small herd of perhaps ten was found in 1905. By 1931, they had increased to about 135 elephants. By 1946 there were between 450 and 560, by 1954, 740, and by 1958 around 1,000 elephants. Since then this herd has increased explosively to number 7,701 in 1968. By then the Game Reserve was devastated and looked as if it had been through a bombardment. Trees had been stripped of limbs and leaves and even uprooted for food. The population of elephants had been allowed to increase unchecked to the point of dangerously overloading their resources of food and so the survival of the habitats was endangered. However distasteful, the herd had to be culled for its own sake. This is what game-management is all about. Herds of elephants elsewhere and also those of hippopotamus, impala, zebra, wildebeest and warthog have had to be similarly culled in other parts of Africa.

By analogy, it is quite possible that the red kangaroo under continual protection would soon increase in numbers to outstrip its supply of food and dangerously overload this resource. Though some pastures would inevitably survive the onslaught somewhere, both plants and animals would ultimately lose. No example of this has ever been studied, but some graziers emphatically claim this cycle of events for some of their paddocks where the kangaroos finally dug up the grass roots for food when the herbage was gone. This should never be allowed. Kangaroos must be shot to save the pastures and ultimately themselves. More would then survive drought in better condition than otherwise. Mr. J. Doohan stated at this Symposium that he was sure that the shooting had in fact had this beneficial effect on the kangaroo populations in the past decade, especially during the drought years of 1964 and 1965, and there is no reason to doubt it. *Selective shooting* of overcrowded kangaroos would do no harm, only good. It is the population of red kangaroos as a whole that must be conserved, not the lives of individuals.

(c) Status as a Resource

The above arguments put a good case for controlled shooting of kangaroos when they are pests both to graziers and to themselves. Why shoot them just to rot, however, when they are of value for meat and skins? During the drought in western Queensland in 1965, when a sheep was worth $0.50, a kangaroo was worth $4.50, yet kangaroos were being slaughtered as a pest. We have had the example of indiscriminate shooting in the past decade severely reducing the herds of red kangaroos and forcing operators out of business

(Newsome and Frith 1966). So why not harvest the red kangaroo on a controlled basis?

The public need not be concerned about conservation of kangaroos under a properly controlled system of harvesting, even though they may be revolted by the slaughter involved. This revulsion is natural enough, for it is a bloody business. However, we must be careful not to adopt a double standard here. After all, the slaughter of live-stock for human consumption, even though at properly appointed abattoirs, is not a pretty affair either. But it is plain that if populations of red kangaroos are to be managed, then a sound strategy is needed for the protection of the populations and the industry.

There are two published attempts to provide a strategy for harvesting red kangaroos. Working on the figures for deaths of pouch-young in drought published by Newsome (1965c), Main (1969) calculated that no harvest of red kangaroos was possible in a severe drought and a small one only in a mild drought. Red kangaroos could sustain a harvest only in good seasons, a harvest he set at about 1 animal in 6 kangaroos. An earlier study of Main (1968) on management of large native marsupials based on their physiological requirements brought out this same point in a different way. Only when both nutrition and the food supply exceeded the animal's requirements (i.e. in good seasons) could their numbers increase.

Winter (1970) has also attempted to devise rules to determine the safe harvest of both red and grey kangaroos in Queensland. He recommended that they be harvested at the rate of 1 in 6.5 animals and no more than one per sq. mile, a similar answer to Main's. There are many crude assumptions and estimates built into Winter's thesis to which he is only too willing to admit. For example, red kangaroos are not evenly dispersed throughout Queensland and are not subject to the same climatic regime to permit one system of harvesting throughout. Also, red and grey kangaroos have been treated as one though they have very different distributions and ecologies. Winter has demonstrated, however, the same very important point as Main: you cannot take as big a harvest from these wild animals as you might think.

Some basic principles and possible limits are ventured below as necessary for a sound management strategy for harvesting red kangaroos. They are based not only on ecological precepts but also on the way sheep and cattle are managed in inland Australia. But one factor is so vital for managing red kangaroos that it needs emphasizing strongly, and that is drought.

Drought is of pivotal importance when planning a sensible way to harvest the red kangaroo. There are three vital considerations:

(1) Drought interferes with breeding and can put a big gap in population recruitment.

(2) Kangaroos are most vulnerable and exposed to shooting during drought.

(3) A reduced, drought-stricken population must be given a chance to recuperate if it is to build up to a level that can sustain harvesting in good seasons.

V. PROPOSED STRATEGY FOR HARVESTING

Our present knowledge makes it impossible to lay down a clear-cut rule-of-thumb; the red kangaroo's range is too large and varied for that. There needs to be inbuilt flexibility that recognises many differences, some of which may be quite subtle. The obvious ones are population density, type of land, climate, and the weather pattern.

Despite these differences in detail, principles for management should be possible, and proposals for them follow.

(1) Only animals older than 4 years at least should be shot. This allows females time to rear a maximum of two young in two years' good reasons.

(2) After drought breaks, depleted populations should be protected from harvesting for a year or more, to allow them to breed up.

(3) Kangaroos should be harvested afterwards while good seasons last. Initially, the harvest should be set at a level to permit populations to recover in no more than two years.

(4) Harvesting should continue into the early stages of a drought to give the remaining kangaroos a better chance to survive the drought and give the graziers respite.

(5) The rate of harvesting should be reduced when drought is prolonged, ultimately to nil, for the heavier the cull the longer it will take the kangaroos to breed up again.

(6) Kangaroo shooters should receive large franchises and be highly mobile to offset the effects of local droughts.

(7) National Parks, such as Kinchiga and the Arid Zone National Park in western New South Wales, should be established as permanent refuges for red kangaroos.

To devise regulations to fulfil these principles for various parts of Australia requires a continuous supply of facts about the status of kangaroo populations and the effect of the weather and industry upon them. There is no substitute for facts if Governments are to control harvesting, which means there must be an adequate number of research workers in the field. However, Governments have had to act to regulate the industry because of the scarcity of kangaroos in places. They have limited both the numbers of shooters and size of the harvest, with the excellent result in New South Wales, at least, that red kangaroos are now becoming locally common again.

Without a satisfactory programme to provide the basic information, however, harvesting of kangaroos must remain largely opportunistic, the conservation of kangaroos uncertain, and the public outcry undiminished.

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THE GREY AND THE RED KANGAROO IN QUEENSLAND

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(Figures 1-3).

The kangaroo problem is complex and many factors have to be considered: conservation of species, stability of an industry, pest status and several social aspects.

In Queensland during the forty years prior to 1917 kangaroos were considered only as pests, control being the responsibility of a variety of district boards. A million pounds as bounty and government subsidies were paid for 26 million scalps of kangaroos, wallaroos and wallabies, and some annual takes approached the million mark. During the next four decades a marsupial skin industry evolved: the monetary reward for killing became a skin price rather than a scalp bonus although as late as 1945 the bounty or bonus system reappeared for some months. The estimated annual harvest of kangaroos for the 30 years prior to 1950 was of the order of 350,000[1].

With the proclamation in 1954 of *"The Fauna Conservation Act of 1952"* kangaroos became the responsibility of the State Conservation Authority. These native animals were declared open season fauna and compilation of reliable data and long-term records was given early priority. A policy of controlled harvesting without detriment to conservation requirements was established, based on an appraisal of field populations.

During the period 1950-1960 the annual harvest of marsupial skins was 450,000, about 90 per cent kangaroos, conservatively assessed as worth £150,000 at the level of prices to shooters.[1]

In 1959 the utilization of kangaroos for meat as well as skins commenced and by 1965, 35 per cent of harvest served the dual purpose. For the years 1961-65 the total harvest was nearly four million, an increase of some 25 per cent on that of the previous five years. Most of this increase involved the grey kangaroo (*Macropus giganteus* Shaw). Estimated annual income of the industry at the level of prices to shooters increased to £450,000.[2]

Detailed analyses of data for the next five-year period are due in 1971. The running totals for working purposes for the years 1966-1969 indicate a mean annual harvest of 900,000.

Since 1959, the first million harvest in recent times, the ratio of greys to reds (*Megaleia rufa* (Desmarest)) has been remarkably constant around 3:1.

KANGAROO POPULATIONS, CONSERVATION AND HARVESTING

During many years of population field research in Queensland with several groups of native animals, particularly small rodents, the usual difficulties were encountered. These were mostly concerned with "closed system" thinking and attempts to transpose small-area results to wider fields. A general conclusion was that, in dealing with native fauna populations over large areas, an approach through population composition rather than depending on estimated densities would be in many instances sounder and much more practical. This largely nullifies the effects of activity and movement which are so troublesome in most field population studies and work.[3]

In populations of native animals living under favourable circumstances there are always appreciable percentages of young and old, and in times of stress the early reduction occurs in these age groups.[3]

When working with population composition a method of estimating adult age objectively and adequately sampling are essential. During the early 1960's a satisfactory method of estimating the age of kangaroos was developed (4a & b) and then field sampling commenced. The age groups being used at present are 1-3 years, 4-9 (the virile part of the population), and 10 years

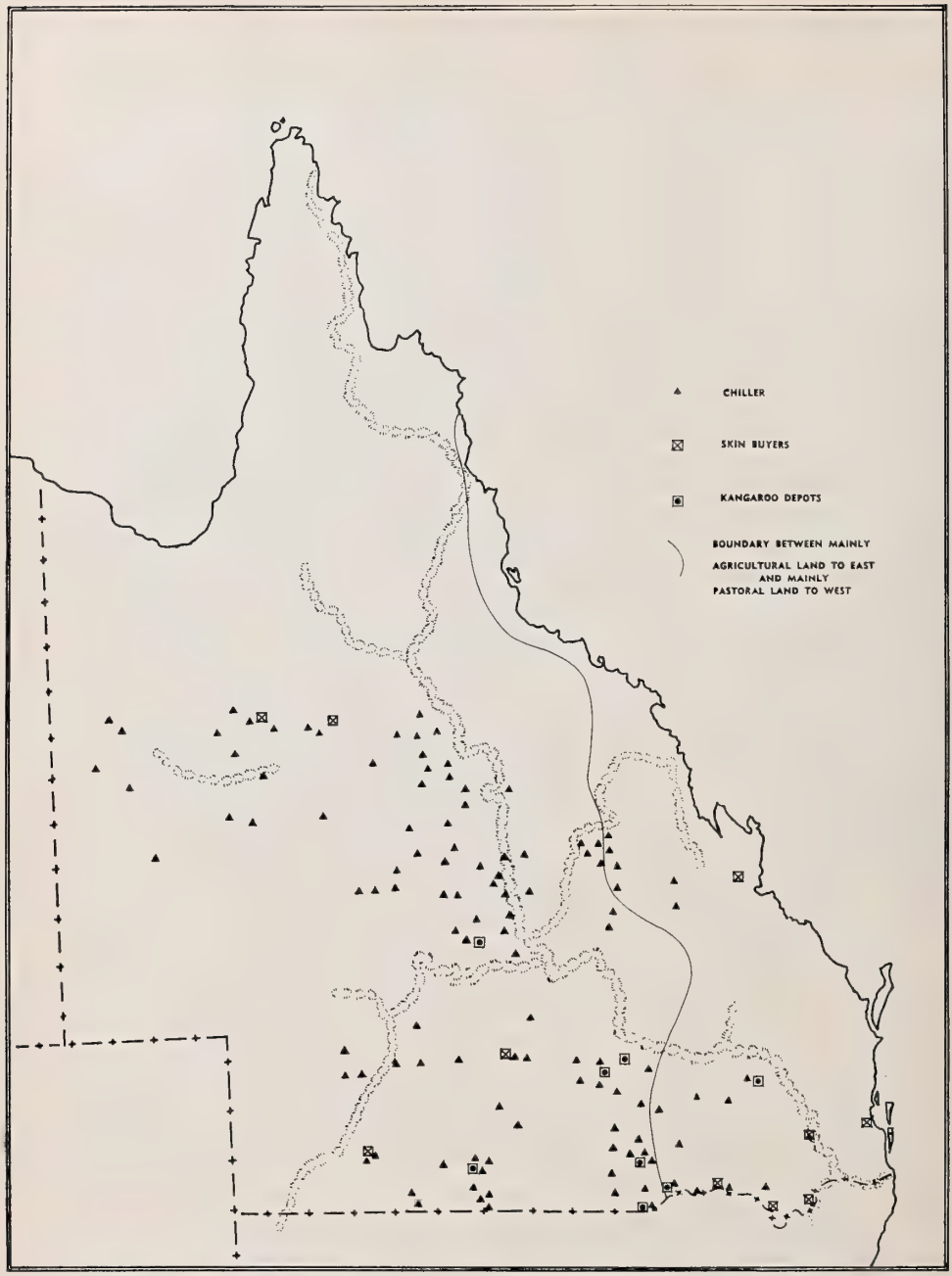

Figure 1:

Year 1967

▲ Location of registered premises (chiller) operated for skins/carcasses by a licensed skin buyer.(a)

X Location of registered premises of a licensed skin buyer for purchasing skins only.(a)

• Location of registered kangaroo depots for processing carcasses.(b)

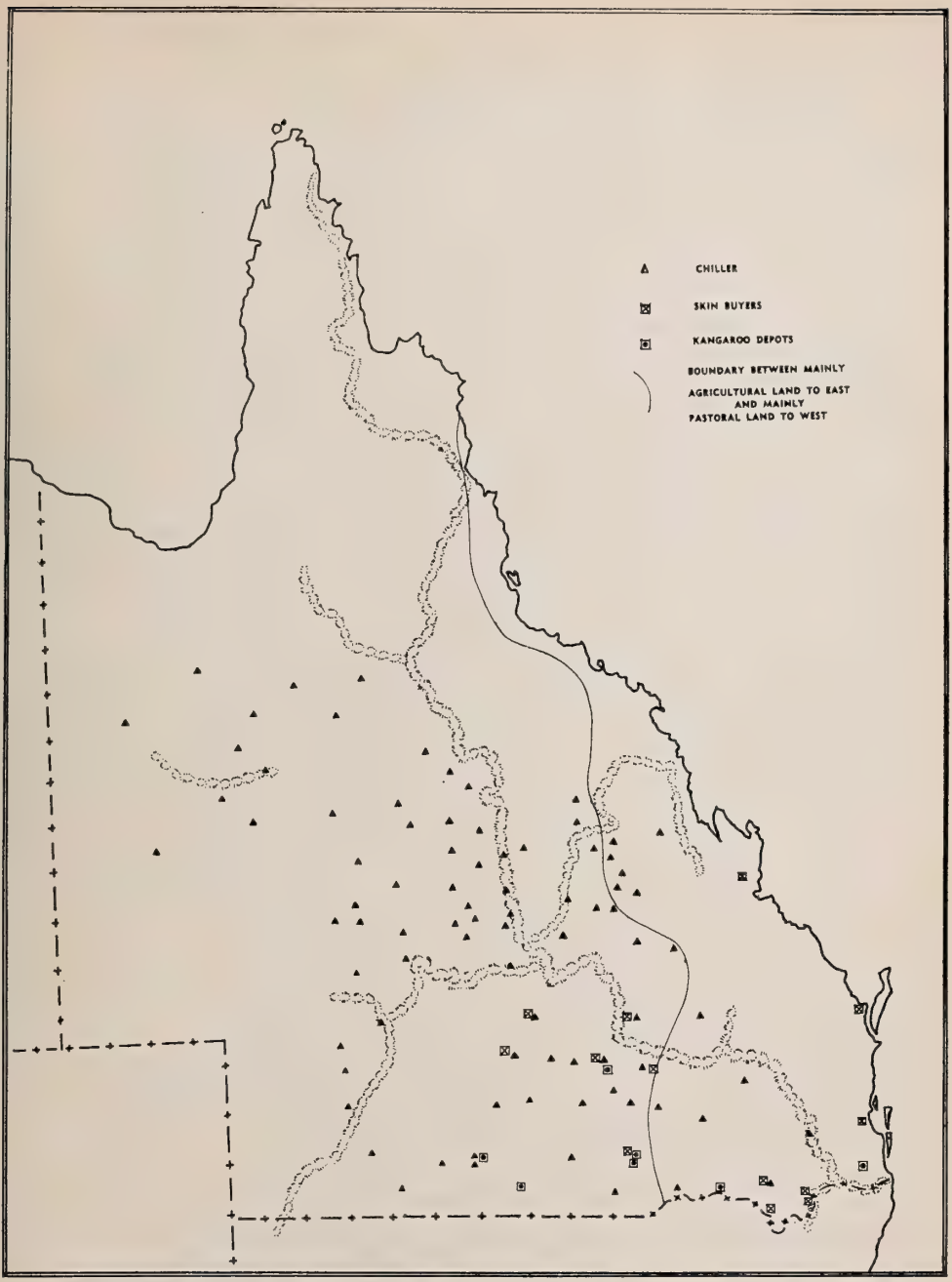

Figure 2:

June 1970

▲ Location of registered "Site of Premises" (site of chiller) operated for purchasing skins/carcasses by a licensed skin and carcass dealer.(c)

[X] Location of registered "Site of Premises" operated for purchasing skins only by a licensed skin dealer. (a)

[•] Location of registered kangaroo depots for processing carcasses.(b)

and over. This dichotomy in adult age is past the mean ecological life spans of our larger macropods, and is in the early decline of population virility: when non-harvested populations encounter stress the early effects on adults are apparent at about 9 to 10 years. Two series of samples are taken, the smaller by professional staff for research covering the three age groups: the other is provided by industry.

Harvesting certainly helps with population samples, and the forms for licenses and permits first used in 1954 were designed to give some indications of relative population densities and dispersals. Despite improvements in many relevant aspects in recent years, routine sampling is still a heavy job and is being given further attention with due consideration to efficacy and cost. In this regard it is worth mentioning that the major area of responsibility is some 400,000 square miles or 250,000,000 acres; figures which, with those of harvests, help people closely associated with kangaroos in Queensland to think in thousands and millions. There are also a further 200,000 square miles which are dealt with by periodic surveys and observations on abundance.[5] [6]

During the past few years there has been an upsurge in the taking of kangaroos in Queensland and in late 1967 a special field survey of the kangaroo industry was undertaken.[7] Following this report and subsequent field work restrictive measures,(c) mainly by controlling chillers and chiller sites, were taken to off-set this occurrence. These follow in principle field population requirements: in some areas the drop in the 10 years and over group was approaching the 10 per cent level at which stage the take of sub-adults was discernible.

For most animal species, there is good correlation between population density and area occupied, except at the extremes of the density range[3]: so the dampening on kangaroo harvest has been applied to the whole harvested area. The objective of course is to keep kangaroo populations in Queensland in a condition to tolerate stresses including harvesting.

Figure 1 illustrates the chillers in operation during 1967, and Figure 2 the registered sites of chillers for June 1970. During 1968 and 1969 the number of chillers operating was at times over 180. This has been reduced to 91.

During the coming few years information on the effects of dampening of harvesting by regulation should become available, and prove of value in the future if the condition of populations ever becomes critical.

CONSERVATION, LAND AND LAND USAGE

At no stage in the long history of kangaroo harvesting in Queensland have fears for the survival of the species been substantiated. The vast area of natural cover within the ranges of both the red and the grey, the fact that a significant proportion of landholders (from 10 per cent to 25 per cent in pastoral districts) do not allow professional shooting,[7] and control of harvesting ensure sound conservation in the immediate future at least. Reduction in sizes of holdings leading to land clearing in the future would however alter the situation.

For nearly a century sanctuaries have been the chief legal link between land and fauna protection, but present thinking is to go on from there and to divide land dedicated for fauna conservation purposes into three classes, that is, 1. Sanctuaries, 2. Refuges and 3. Fauna Reserves.

1. *Sanctuaries*: These are private and Crown lands, of either small or large areas, on which conditions for taking fauna are covered by legislation. Most National Parks, Forestry Reserves and State Forests are also designated as fauna sanctuaries.

2. *Refuges*: These would usually be areas on which the conservation authority would have more control over fauna and habitat than it has at present in

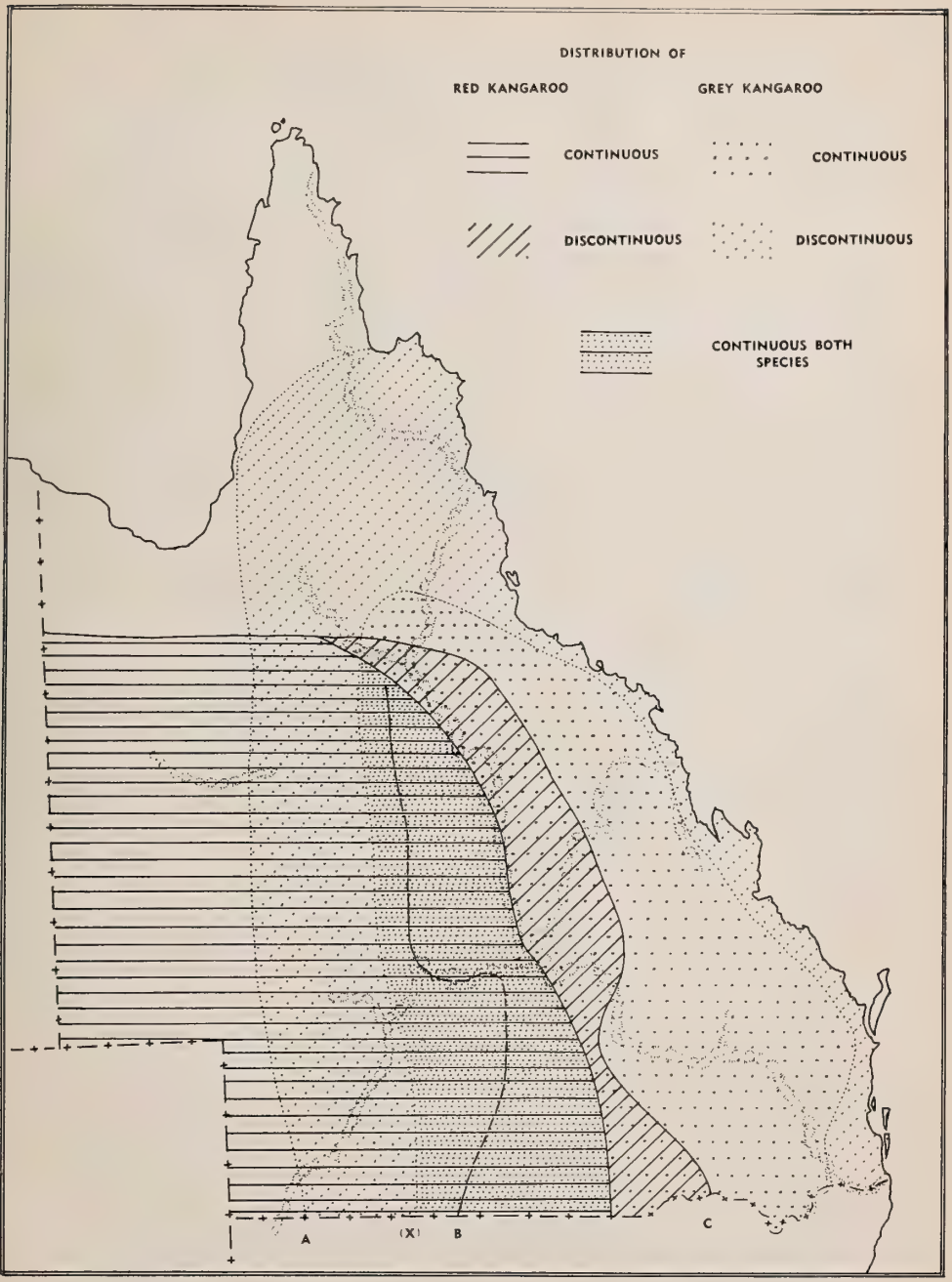

Figure 3:

Distributions of the grey and the red kangaroo superimposed.[8] [9]
Harvesting according to species. West of boundary A, 100 per cent reds; line B, 50-50; east of boundary C, 100 per cent greys.
(X) Western boundary of continuous distribution of both species.

sanctuaries. This type of area, by experience elsewhere, would be equivalent to what are sometimes called multi-purpose reserves, and would be for specific fauna purposes. For example, some marsupials are uncommon and limited in distribution. Excessive shooting or undue interference with the countryside could lead to disappearance of the species. At the same time it would be neither practicable nor desirable to interfere to any marked degree with current commercial enterprise on the property. Generally, a refuge would be a leasehold property devoted to some primary industry.

3. *Fauna Reserves*: These would comprise a limited number of comparatively large areas under the direct control of the conservation authority and reserved strictly for fauna in their native and undisturbed environments. Experience indicates that where such reserves exist they serve as reservoirs from which the habitat outside may become repopulated when conditions are suitable.

Figure 3 is presented in conjunction with Figures 1 & 2 mostly for record purposes. To avoid clouding the main issue it will not be used at this juncture to assist in discussing a number of possible subjects such as, the relationship of mountain ranges watersheds and kangaroo dispersals, inter-specific competition, the possible consequencies if the western boundary of continuous distribution of both species is advanced westward, and the effects on far south-western red kangaroo populations of epizootics recorded in the summers of 1962-1963 and 1965-1966. It is opportune however to point out that the greater portion of the State's human population, and most of the 14,000,000 acres of gazetted sanctuaries[10] are in the eastern lands which are mainly used for agriculture. There the harvesting of kangaroos is negligible and populations of the grey kangaroo are in good condition:

Most of the red kangaroo country and about half of that occupied by the grey are west of the Great Dividing Range, and that area is for all practical purposes a huge refuge where detrimental interference with habitat is not intensive and harvesting is still selective.

Queensland has lost none of its fauna species although there is evidence that the population condition of some has been weakened in southern parts of the State. During the 1960s that of kangaroos suffered from an influx of chillers and shooters from southern States and the adverse results are now being rectified (see Figures 1 and 2).

What is the future of kangaroos? Do we settle for ultimate preservation in a few enclosed areas, or plan and act for conservation, and harvesting where practicable over an area of some 600,000 sq. miles? There is still time for the latter course in Queensland, and establishment of the principle of refuges is considered a first essential: implementation to come concurrently with development and changes in land usage.

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DISCUSSION

Rapporteur, J. R. Simons, School of Biological Sciences, University of Sydney.

SIMONS: We have just heard two very different approaches to the problem of control and conservation of the kangaroo. Dr. McDougall has explained the rationale of the methods as practised by Government in his State. As he has shown, the methods are working reasonably at the moment and he has every reason for thinking that they will be satisfactory in the future. But while this may be true, and while they are undoubtedly administratively convenient, they do seem to me to be empirically based and operate, as it were, from the industry down through the kangaroo population. Dr. Newsome's approach, on the other hand, would work in the reverse direction. His study is more fundamental and, to my mind, it is an extremely important contribution to our symposium in that he has presented information and ideas which must be taken into account in our thinking about the control and conservation of the macropods, and other marsupials, right, so to speak, from the ground up.

One of the first points he made is that under modern conditions, from the advent of white men into Australia, the population of the red kangaroo has probably increased tremendously, and he made the point that some of our early explorers would not have died had the kangaroos been in the numbers that they now are. He then went on to explain why the red kangaroo has managed to increase its numbers and he pointed out that there is a movement between the woodlands and the plain lands, depending upon the conditions of drought and aridity: and then at the end he went on to some very important points for the conservation and the possible cropping of the kangaroo. These are ideas which have not been presented in this form before.

Question from Mr. Baines, of the Flora and Fauna Protection Society of Brisbane:

BAINES: The Department of Primary Industries repeatedly claims that the killing of kangaroos for pet meat and skins has had no noticeable effect on kangaroo populations in Queensland—and he goes on to say that from his personal observation the shooting has been in the 2 to 3 year old age group and this means that these kangaroos have not been able to reproduce for the first time. How can the Department arrive at the conclusion that the rate of killing does not greatly exceed the rate of natural increase?

McDOUGALL: Our method of approaching population work avoids small details and so far as conservation is concerned unnecessary interference with

the kangaroo industry. We know undesirable things happen, but if we can obtain 85 per cent efficiency at little cost, we are not going to spend thousands to pick up the details of the other 15 per cent.

If population surveys show that in the interests of conservation further dampening on harvesting is required, then this will be done.

Question from Mr. E. M. Fox, M.P.

FOX: Dr. McDougall showed that the number of licensed chillers in Queensland had been drastically reduced. Could he also say whether the number of licensed shooters has also been reduced, and if so to what extent?

McDOUGALL: We do not discriminate amongst people. If some want to do a little hunting and others to shoot for profit that's entirely up to the operators. If they want to employ a lot of shooters and kill too many kangaroos then further dampening will be the result. We use registering of shooters mostly for research purposes.

LIVANES: Can Dr. McDougall give any information of the depth to which red kangaroos penetrate into forest country in good seasons?

NEWSOME: What is meant by "forest", do you mean the tall eucalypts?

LIVANES: I'm thinking of the interior country that we are talking about. We have mulga—reasonably dense, and we've got plain areas. The mulga woodlands aren't just thin strips—they appear to be quite a reasonable distance across, and I wonder if there is some significance in that—or does it exist in marginal areas?

NEWSOME: No, they're right through the mulga. On an average depth calculated at 2½ miles, and there are about six miles of these woodlands. And you must remember that creeks flow through the woodland and out into the spinifex. Much of the water floods out into the woodland.

SIMONS: Mulga wood is a very thin type of forest.

NEWSOME: It's impossible to drive a Land Rover through it.

SIMONS: A question from the floor for Dr. McDougall:

Can Dr. McDougall tell us what changes have taken place in the age structure of the grey kangaroo in Queensland over the past 5 years?

McDOUGALL: I am leaving that to the research men and their technical papers.

My concern in this general paper is that the conditions of kangaroo populations in Queensland at the moment are satisfactory.

SIMONS: Another question from the floor for Dr. McDougall: has the Queensland Government thought of buying out some of the farmers now experiencing hardship and making one large park similar to Kruger Park in South Africa?

McDOUGALL: I thought we had answered that. What is the future of kangaroos in Queensland? Do we settle for one reservation in the future? No one seems to be able to nominate the size or the price. Or do we keep going and maintain the kangaroos distributed over 600,000 sqare miles. As pointed out, we are still mostly Crown Land.

Question from Mr. P. E. Roberts, Royal Zoological Society:

ROBERTS: Do stock fences have any serious effect in restraining the migration of kangaroos between woodland and plain?

NEWSOME: Not in Central Australia where they are just standard cattle fences—three strands of plain wire. Sheep country is another matter

because people tend to fence for rabbits with netting. This means that the kangaroo has to jump a fence. I have never myself studied kangaroos in that situation but other people have. Dr. Frith may have a comment on that.

FRITH: It is almost impossible to get accurate meaningful data on this. I think it is certain that fences do interfere with the movements of kangaroos. Very few kangaroos that I have watched will go over a rabbit fence unless it is to dodge a Land Rover or something else on its tail. I think that kangaroos would get over a fence to avoid really severe drought. I think their normal movements are considerably influenced by extensive rabbit-proof fencing. I don't believe in the use of the word "migration" applied to kangaroos. It is better just to refer to movements.

LIVANES: One point of discussion would apply to graziers. When kangaroo shooters dismember the 'roos they shoot overnight to bring them into the chillers, they leave a lot of mess lying about. It becomes infested with maggots and proliferates the blowfly menace, which accentuates an already serious problem for the graziers. Does this come into the thinking of the Department of Primary Industry which is primarily concerned with the graziers' interests?

RATCLIFFE: I think I might answer half of that question. The blowflies that strike sheep are not the ones primarily breeding on the living sheep—it's very specalised. This came out as a surprising result of research on these insects.

SIMONS: Thank you. I would like to return to one of the points in Dr. Newsome's paper that interested me; namely his deduction that macropods—or at least the red kangaroo—had increased with the introduction of the pastoral industry. I wonder whether there are any other examples of such increase that he, or anyone else here, might know about. Are there any hard figures available?

NEWSOME: The euro or hill kangaroo increased in numbers quite fantastically in the Pilbara District of Western Australia. This is work that the C.S.I.R.O. Wildlife Research men have done. The number poisoned at waters was just beyond belief; up to ten to the square mile in some areas. As the numbers of euros increased and the sheepmen began to complain, the numbers of sheep fell away, and so did the breeding of the sheep. So the euro was blamed; but in fact the root cause of both of these changes was the impact of sheep grazing on the pastures. The pastures were made up of soft nutritious grasses, originally along the plains, the creeks and the lower lying country. Spinifex inhabited the rocky outcrops where euros were restricted, it seems, in early times; but the sheep ate out these better grasses almost to extinction, and the spinifex spread out over these plains. Now this gave the euros an enormous amount of fodder. Another effect that the sheep farming had was to provide the euro with many more watering points. The euro's problem was two-fold: avoiding heat, and getting drought fodder. These things were solved by sheep coming. After poisoning off the euros, controlled burning of the countryside allowed the good pastures back in. Now sheep can be run on some of these properties again. But there is no doubt that the earlier degradation was caused by the sheep in the first place. I don't know about the grey kangaroo. Work on the agile wallaby in North Australia indicates a similar relationship to exist between the water buffalo and the wallaby.

STRAHAN: I think that the last remarks could well lead into a statement on the findings of the C.S.I.R.O. on the diet that is shared, to some extent, by sheep and kangaroos. It would be pertinent if perhaps Dr. Frith or one of his colleagues would put forward the facts on the distribution of diet between sheep and kangaroo in times of drought and times of plenty.

FRITH: This is one of the points, I'm afraid, that Dr. McDougall has referred to as "the details", and "the small pieces of work in small areas". I would not like to see the results extrapolated too far. Dr. Newsome has

mentioned the results of Chippendale's work in Central Australia which we know was based on 145 stomachs and 54 in the drought. The work of Dr. Griffiths was in one paddock on one sheep-station in New South Wales/ Queensland over two years. I can't quote the exact results but there were red kangaroos, sheep and grey kangaroos all inhabiting the one paddock. He shot samples of the three species regularly and examined their stomach-contents. He found differences in the diet selected by these three particular animals. The sheep would concentrate on one group of plants, the red kangaroos would concentrate on another, and the grey kangaroos would concentrate on another. It was a time of moderate drought and his general conclusion was that none of these three animals was in direct competition for food, but nevertheless there was some competition. I think the only reasonable summary would be that kangaroos and sheep are not in 100 per cent competition at all times or the degree of competition is not so great as people commonly suppose. I would not like to go much further. Dr. G. Storr did a similar study in the northwest of Western Australia with red kangaroos—euros or hill kangaroos and, again, sheep. He produced practically identical results: that the sheep and these two species of kangaroos were not in direct competition all the time. As I said earlier, I wouldn't like to see this extrapolated to the point of saying that kangaroos do not hurt sheep farmers: they do. In Queensland, Dr. Kirkpatrick has studied the grazing habits of grey kangaroos and made some observations on sheep, and turned up with results similar to those I have mentioned. Now that we have all these studies pointing in much the same direction, it is obvious that there is a great need for a large-scale, proper study of these grazing preferences of these animals.

McDOUGALL: Just one point I wish to mention as regards Mr. Kirkpatrick's work on feeding: quite a lot was done, but we decided a great deal of money would be required to obtain worthwhile results, and as a conservation authority these would be of little value to us. Some of the information in Figure 3*, offered without comment, relates to this subject.

* Of Kirkpatrick & McDougall's paper in this Symposium, page 55.

THIRD SESSION: ECONOMICS OF KANGAROOS

Introductory Remarks by the Chairman, Mr. H. J. Frith, Chief, C.S.I.R.O. Division of Wildlife Research.

FRITH: I would like to make just two points. We are dealing with the economics of kangaroos and this involves shooting. Many people accept that there are two main situations in which large numbers of animals are deliberately shot or killed. The first, where they are adversely affecting agriculture and it is in the national interest to reduce their numbers, is a pest control operation. The other is where an animal population is capable of providing a saleable resource and contributes to the national income. Many people believe—and many do not believe—that in this situation it is quite ethical to use that animal for that purpose. It is within those two systems, I think, that most of the speakers will talk this afternoon.

The kangaroo situation in Australia resembles an inverted triangle. We might imagine a kangaroo industry sitting at the top of this triangle supported, in the middle of the triangle, by the property of the long-suffering graziers or pastoralists. The grazier ultimately supports the kangaroos and the kangaroos in turn support the industry.

Clearly there is a number of questions to be asked. If the kangaroo is a pest one would think that most research should be directed towards eradicating that pest. Using modern technology, kangaroo populations could theoretically be wiped out completely by the use of 1080 or similar poisons dropped from aircraft. Under those conditions it might be legitimate to harvest the animals for another purpose because then somebody would have an economic stake in maintaining kangaroo populations and the pest operation would be dealt with. Somebody would make some money and by having the financial incentive the kangaroo population would never be eradicated.

There were to have been four speakers in this session: the first one was Mr. Macfarlane of the Department of Primary Industry, who was to have spoken on the size of the present export trade in kangaroo meat. He has been unable to attend but he sent a printed paper.* The other three speakers are: Mr. Doohan, a grazier, who will tell us how hard this triangle sits upon his industry; another speaker is Mr. Livanes, who will tell us how hard his industry sits upon the kangaroo population; and the last speaker, Professor Sharman, I hope, will tell us which system is right or whether the triangle will topple over.

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* See page 62.

EXPORTS OF KANGAROO MEAT

by J. D. MACFARLANE
Department of Primary Industry, Canberra, A.C.T.

Prior to 1956, Louis Carsten and Company of Perth had opened up an export trade in kangaroo meat for human consumption, but little was known about this trade until 1958, when interest in exports developed and a number of new packers entered the trade. In 1959 there were very considerable exports of kangaroo meat, particularly to Germany, and interest in the trade was maintained.

During the ensuing 9½ years, 25,287 tons of boned-out kangaroo meat have been exported to no less than 45 countries and an examination of the export figures provides a most interesting trade pattern.

In 1960/61, when Germany imported 3.7 million lb., total exports approximated 6.2 million lb. However, in 1960 the German market collapsed and exports in 1961/62 fell to 2.9 million lb. New markets emerged and by 1964/65, when Japan imported 7 million lb., exports reached a peak of 11.2 million lb. However, some of these new markets could not be held and by 1968/69 exports had shrunk to 2.2 million lb. (A schedule of exports over a period of years is appended).

The reason for the rather dramatic fluctuation and reduction in the level of exports is found in the gradual build-up of restrictions by overseas countries on the entry of kangaroo meat, rather than in a decline in prices or non-availability of supplies.

There is evidence that in 1960 in Germany there was strong opposition from local meat producers to the importation of kangaroo meat and the product received very unfavourable publicity. The following extracts from German newspapers are typical of the atmosphere which existed:

> "Hanover—20th July, 1960.
>
> West Germany: Worms found in chilled kangaroo meat.
>
> From the beginning of 1960, venison and butcher shops in West Berlin have offered for sale chilled kangaroo meat imported from Australia. The meat, taken mainly from the hind legs of the animals, is a dark red-brown colour, has a wholesome smell like beef and is readily bought on account of its low price.
>
> "Complaints have been received by the veterinary authorities that 'living worms' had been found when the meat was fried. It was ascertained that there were no living worms in the meat, but the samples contained parasites, usually bundled in a sheath between the muscles. The worms, classified as *Dipetalonema websteri* were about 3½ inches long and 1/25th of an inch in diameter.
>
> "It is obvious that kangaroo meat containing a high perecntage of worms is unsuitable for human consumption. It is therefore suggested that the importation of chilled (frozen) kangaroo meat be prohibited by the veterinary authorities regardless of commercial considerations."
>
> "Hamburg—15th August, 1960.
> 14 centimetre, about 6 inch, worms found in kangaroo meat.
>
> Doctor H. S. Bathel, has demanded a complete stoppage of imports, irrespective of business interests which may be affected. In an article in the *Records of Food Cleanliness,* Dr. Bathel writes: 'There is no doubt that this kangaroo meat is to a very large degree infected with worms. It is a nauseating and deteriorated food and is therefore not suitable for human consumption'."

Finally, in April, 1964, an Ordinance was introduced in Germany prohibiting the sale of kangaroo meat for human consumption except when in hermetically sealed containers. The official reason given for the German action was the high incidence of salmonella in kangaroo meat imported into Germany.

No additional official complaints about the finding of worms in kangaroo meat were received until 1969 when the Hong Kong authorities condemned considerable quantities for this reason. Subsequently, the Hong Kong authorities decided that as from 1st April, 1970, the importation of kangaroo meat would be prohibited unless the meat was accompanied by a certificate from the Department of Primary Industry attesting to its fitness for human consumption. The reasons for this action were stated to include the level of infestation by parasitic worms and worm nodules.

The market for kangaroo meat in the United Kingdom has been very variable but reached a total of 4.1 million lb. in 1966/67. It is not known whether this meat was imported for human consumption or for fresh pet food, but the latter use appears to be the more likely. In November, 1969, the United Kingdom authorities introduced the Meat (Sterilisation) Regulations which prohibited the importation of meat for human consumption unless such meat was supported by a certificate from an approved exporting country attesting that the meat was fit for human consumption. Meat not covered by such a certificate may be imported only if sterilised under prescribed conditions.

The market in Japan for Australian kangaroo meat has fallen from 7.5 million lb. in 1965/66 to 304,000 lb. in 1968/69. It has been suggested that the reason for this slump in imports is related to increasing pressures from Japanese processors and consumer organisations to prohibit the importation of kangaroo meat.

Since 1959, representations have been made, from time to time, by exporters of kangaroo meat for the Commonwealth authorities to bring kangaroo meat under the provisions of the Exports (Meat) Regulations, and thus accept responsibility for the inspection and certification of this product. For a number of reasons the Department of Primary Industry, which is responsible for the administration of the Regulations, has not been prepared to support this action.

There have also been numerous representations from persons and organisations for the export of kangaroo meat to be prohibited. These representations have been considered in detail on several occasions at meetings of representatives of interested Commonwealth Departments and the official Commonwealth attitude has been that so long as the State Fauna Protection Authorities permit the controlled slaughter of kangaroos there is no justification for a prohibition on the export of kangaroo meat.

In an endeavour to improve the standard of kangaroo meat shipped overseas, the Australian Kangaroo Meat Exporters' and Packers' Association was created. (The former name of this organisation was "The Australian Kangaroo Meat Exporters' and Packers' Committee"). Members of this organisation gave an undertaking to offer for shipment "only such frozen kangaroo meat which had been processed and packed in hygienically sound premises, inspected and approved by an inspection authority approved by the Australian Kangaroo Meat Exporters' and Packers' Committee" (Now Association). The meat was required to be subject to inspection and certification by an approved commercial inspection authority prior to shipment.

These voluntary conditions imposed by the Association on its members did much to maintain kangaroo meat exports at a good standard. However, the higher standards required by importing countries for meat generally in recent years have led to the exclusion of kangaroo meat from the major markets.

The future of the export trade in kangaroo meat is uncertain. Much will depend upon the overseas demand for kangaroo meat for pet food, and the prices offered.

SHIPMENTS OF KANGAROO MEAT
LB.

COUNTRY	1960/61	1961/62	1962/63	1963/64	1964/65	1965/66	1966/67	1967/68	1968/69	1969/70 to December
Bahamas Is.	—	—	—	—	1,200	—	—	—	—	—
Bahrein	—	—	—	—	—	1,080	1,740	1,150	5,820	2,150
Belgium	780	43,920	—	—	—	—	—	—	—	—
Borneo—North	—	180	—	120	—	—	—	—	—	—
Ceylon	—	60	—	—	—	—	—	—	60	—
China—M'land	1,120	2,240	—	11,160	—	—	—	—	—	—
Denmark	—	—	—	—	—	3,885	—	—	—	—
Fiji	5,232	3,760	—	—	—	—	—	—	300	—
France	—	120	—	—	—	—	—	—	—	—
French Polynesia	—	60	—	—	—	—	—	—	—	—
Formosa	960	—	33,540	—	—	—	120	—	—	—
Germany	3,699,673	560,394	490,760	730,830	—	—	—	—	29,710	—
Ghana	—	2,340	—	22,200	6,780	108,160	—	—	—	—
Greece	—	—	—	—	10,130	—	—	—	—	—
Hong Kong	100,077	670,008	498,520	809,114	1,024,883	1,326,660	1,075,210	2,291,800	1,347,052	725,460
Iceland	—	—	—	—	—	8,700	—	—	—	—
India	—	—	6,000	—	—	—	—	—	—	—
Italy	—	—	—	60	—	—	—	—	—	—
Jamaica	—	—	360	—	—	—	—	—	—	—
Japan	1,441,862	594,736	651,876	3,214,381	7,093,390	7,565,251	3,159,361	701,960	304,430	208,080
Kuwait	60	—	—	—	—	—	1,930	300	900	300
Liberia	—	1,080	—	—	—	—	—	—	—	—
Malaya	407,435	269,958	390,080	449,566	—	—	—	—	—	—
Malaysia	—	—	—	—	590,506	625,554	176,530	112,590	99,570	69,060
Mauritius	175	—	—	—	—	—	—	—	—	—
Mexico	—	60	—	—	—	—	—	—	—	—
Netherlands	218,251	3,600	15,120	35,520	33,570	—	—	—	—	—
Netherlands-NG	1,620	2,340	—	—	—	—	—	—	—	—
New Guinea	8,872	—	—	—	—	—	—	—	—	—
Nigeria	—	9,060	—	—	—	—	—	—	—	—
Norfolk Is.	—	—	—	—	—	600	—	—	—	—
Norway	120	—	—	180	74,640	50	—	—	—	—
Okinawa	—	—	—	—	—	—	6,000	—	—	—
Other Foreign	—	—	1,200	—	—	—	—	—	—	—
Pacific Is. Other	—	—	180	—	—	—	—	—	—	—
Papua-NG	4,548	3,800	400	500	1,440	1,618	785	431	—	2,310
Philippines	—	930	—	40,020	79,920	39,960	120	—	335	—
Sarawak	—	1,620	400	14,430	—	—	—	—	—	—
Saudi Arabia	—	120	—	—	—	—	—	2,400	600	—
Singapore	204,350	626,764	13,260	6,840	—	26,880	6,600	—	—	—
Solomon Is.	—	160	—	—	—	—	—	—	—	—
Spain	—	118	180	60	—	—	—	—	—	—
Thailand	—	—	—	—	—	—	300	—	—	—
Tonga	—	4,690	—	—	—	—	—	—	—	—
Trinidad	—	—	—	4,500	2,220	2,200	—	—	—	—
Truc. Sts.	—	—	—	—	—	—	—	—	2,730	1,160
U.K.	43,998	62,520	38,240	109,170	2,190,683	1,476,104	4,104,241	934,138	431,740	1,092,780
U.S.A.	24,360	360	—	1,420	86,980	22,440	—	—	—	—
TOTAL LBS.	6,163,493	2,864,998	2,139,716	5,450,071	11,186,342	11,742,732	8,532,937	4,044,769	2,223,247	2,106,100
TOTAL TONS	2.752	1.279	955	2.433	4.994	5.242	3.893	1.806	993	940

Grand Total for 9½ year period—Tons: 25,287

THE KANGAROO AS A PEST

by J. J. DOOHAN
Graziers' Association of New South Wales, Sydney.

It is ironical that a species of animals which apparently lives together in perfect peace and quietness without any suggestion of animosity, jealousy or violence within the species, an animal with a quaint and gentle nature should at times evoke such massive emotional response from the public at large—so deep and of such an order as to make extremely difficult any calm logical discussion about its future. It is for that reason I am pleased to be here to take part in this Symposium, where I feel we all basically have the same objective though of course we may differ in our ideas of the way that this may best be achieved.

As a grazier, I am aware that I belong to a section of the community which is looked on by some people as a group of ruthless murderers so far as the kangaroo is concerned: a group of people who seek to have the kangaroo exterminated. This of course is a fallacy. If the last kangaroo in Australia were to die, I firmly believe that it would be graziers who would mourn their loss more than any other group of people.

Make no mistake, however, that we as farmers and graziers are very conscious of the fact that an over-population of kangaroos causes (1) a very serious setback to our economic returns as individuals, (2) reduces the productivity in the pastoral and farming industries generally, and (3) has a very real detrimental effect on the wealth of the nation.

The greater part of my practical knowledge of this subject which has been allotted to me, "The Kangaroo as a Pest", has been gained in the huge pastoral zone of the State of New South Wales but, because I have been associated with various State and Federal industry organisations for a number of years, I know that the problem is far from unique for this area, that it is a problem of some magnitude over a much wider field.

As a child living with my parents on the Darling River I cannot remember any great controversy about kangaroo populations, in fact I cannot remember that kangaroos reached plague proportions such as we have known in the past 20 years. There are several reasons contributing to the increase in kangaroo population which the Western Division has experienced over the last 2 decades: 1, Grazing of these pastures has made the foliage more suited for the palate of the kangaroo; 2, the provision of good permanent watering facilities which have been provided for stock; 3, the introduction of myxomatosis and the reduction of the rabbit population; and 4, that during the first 6 or 7 years of the period very few kangaroos were destroyed (this being due to there being a state of full employment in the community and the fact that kangaroo skins were of no great value). Most station properties worked short-handed and had little time to pay attention to the control of kangaroo populations even though there was, at that time, a continuous open season).

WHY DO KANGAROOS AFFECT THE FARMERS' AND GRAZIERS' ECONOMIC RETURN?

This surely is quite obvious, no matter how few kangaroos one has on his property there is no doubt that they compete with the livestock, with the sheep and the cattle, for food and for water. Kangaroos seek fresh young feed and take the best and most fattening of the available pasture. I cannot accept for one moment that kangaroos eat a different type of pasture than sheep and cattle and therefore are not competitive. This is to me an absolutely false assessment of the true situation. In fact, kangaroos by their very nature are able to devour short fresh green pasture before it is long enough for a sheep or a beast to get hold of it.

They compete with stock too in the use of water and though this is at first may not seem to matter very much it must be realised that in fact on some properties it is all-important. There are paddocks where the water supply is barely sufficient to make full use of the pasture therein. At other times water has to be carted to stock in a paddock. However, I am quite confident that farmers and graziers speaking generally are prepared and in fact desire to maintain an acceptable population of kangaroos on their properties.

OVER-POPULATION

Over-population of kangaroos adversely affects primary industries in a number of ways.

1. The kangaroo makes serious inroads into the available grass and herbage, and this throws the entire management programme out of order. For example, until recent times of high kangaroo populations, it was good and common practice to spell a proportion of paddocks in rotation so that each could develop good pasture growth. This procedure has now ceased because, if one leaves a paddock to spell, kangaroos congregate upon it from miles around. The grazier is not merely providing rations for kangaroos that he might quite willingly have allowed to breed on his own property: he is feeding animals from the entire neighbourhood.

2. Kangaroos have a serious effect on crops in the wheat-sheep zone. Not only does the farmer lose what is actually eaten by kangaroos, but he also suffers from the loss of crops beaten down by their intrusion.

3. Kangaroos damage fences, adding substantially to the cost of maintenance.

4. Kangaroos foul the soil in areas where they congregate, particularly where they rest under trees in summertime, and the soil may not recover for up to three years.

5. They compete with livestock for water when the supply is limited.

Apart from causing economic loss to farmers and graziers the kangaroo is a pest and in fact a very serious hazard to motorists at night. Invariably the dazzling headlights draw them directly towards the vehicle. Motorists at all times in these areas must travel steadily, be alert, and in times of over-population progress can be pathetically slow as the motorist is continually braking suddenly and swerving to miss the onslaught.

Needless to say because of the disturbing adverse economic situation of both the wool and wheat industries at the present time the necessity to prevent over-populations of kangaroos becomes very real indeed.

If by any chance there is anybody here present who thinks that graziers complain unnecessarily I can quote for you a few figures that may convince you of what magnitude this problem can be. In the year 1962 for the five month period from July 15th to December 15th a chiller on my property paid the shooters for 205,425 lbs. of kangaroo meat. At this time only the kangaroo butts were being marketed and, allowing as I do, for the average butt to be 28 lbs. in weight, this means that that chiller handled 7,336 kangaroos in the period of five months. These kangaroos were taken from my property and from the two properties adjoining but the greater part of the shooting was done on my property and it is conservative to say that at least half these kangaroos were taken thereon. Not only during that period was I providing for something over 3,600 kangaroos but the fact is that at the end of the period the kangaroo population was still very high indeed and appeared to have been reduced only relatively slightly. My property in those years was carrying about 6,000 sheep and about 200 head of cattle, so in all probability more pasture was utilised to feed the kangaroos than was utilised for the stock. These figures are quoted only because they are figures that are known to me. There are other totally convincing figures quoted in the various areas of the west.

I think it is important too to recognise that, quite contrary to the beliefs of a lot of the misinformed public at that time, the taking of kangaroos contributed very much to their survival. It must be recognised that any grazier in an area subject to drought reduces his stock population when he fears the onslaught of disastrous drought. In so doing his smaller numbers will survive for a longer period and this of course was very true in this instance in regard to the kangaroo population. There is no doubt whatsoever, that, if the population of kangaroos had not been reduced in the years 1959 to 1963, the years before we saw in 1964 and 1965 the worst drought possibly on record, certainly since the drought of the turn of the century in 1901-1902, the drought would have been serious so much sooner, with a higher population of kangaroos, and would have therefore been of a longer duration and without a doubt a smaller number of kangaroos would have survived.

Older inhabitants of the Western Division of the State see no risk whatsoever of the red or the grey kangaroo becoming extinct. Some believe that it is the political repercussions of the outcries of the ill-informed through the press, the radio and other places that has caused the authorities to place more rigid control on the taking of kangaroos, which is quite unnecessary for the survival of the species.

Country people have a love of freedom, that is why they choose to be country people—Heaven knows they give up the opportunities of the pleasures and conveniences of amenities available elsewhere. They are obliged to control other pests on their properties and feel they are losing their freedom in respect of kangaroo management. This view is very understandable and, if it is the survival of the species only about which we are concerned, has a lot of merit. Even with present lucrative markets for kangaroo skins and meat there is somewhere a trigger print of a low population which makes shooting unprofitable.

It is recognised however, that without supervision of any kind, the populations of red and grey kangaroos could become unacceptably low.

CONCLUSION

We have got to make people aware of what the problem is. We here who today have demonstrated our interest have a duty to become better informed and we must endeavour to inform the public so that more logic can be brought into discussions of kangaroo management. I began by saying that it was ironical that such a quaint and gentle animal should evoke such massive emotional response and I end by saying that it is possibly because this animal has a quaint and gentle temperament that people become so disturbed at any thought that they may be brutally treated. What is essential is good management with a minimum amount of red tape—healthy discussion with a minimum of red faces and most emphatically never brutality.

KANGAROOS AS A RESOURCE

by THEO LIVANES
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Because kangaroos enjoy a special place in the hearts of most Australians, discussions of the utilisation of this resource display more emotion more often than do discussions of any other resource utilisation. Some object to any use, whilst others deny that kangaroos are a resource at all, but are on the contrary a pest that prevents the full utilisation of the land and water resources.

There can be no doubt that kangaroos can be utilised in many ways, but some believe that commercial utilisation should be prevented because it will destroy the resource and thereby deny all other uses. I am satisfied that kangaroos can be used commercially, to produce valuable products, and provided Governments exercise control properly, this utilisation will not only hold the industry's propensity to do damage in check, but will have a population stabilising effect.

I intend briefly to mention some of the non-commercial uses of kangaroos, then to mention equally briefly the commercial utilisation of kangaroos in the past and finally I intend to outline the way I feel harvesting industries should be directed.

Those of us who would like to see kangaroos left free from human use or competition have no hope of achieving this objective nationwide or even Statewide. National Parks should provide protected habitat islands dotted across a land where other land uses prevent the kangaroo populations from enjoying these conditions. To be more than zoos these areas need to be large enough to enable the protected population to be viable under all conditions.

At some, or all of these kangaroo-orientated environments, iti could be possible to provide for other utilisations of kangaroos. The kangaroos living in such areas would not be under pressure from their human neighbours and would therefore be more likely to pose for observation or photographs and could thereby satisfy many nature-lovers and tourists.

Sporting shooting of kangaroos does not seem to me to be necessarily incompatible with other utilisations. If properly regulated the sporting shooter could provide a useful pruning service in areas where the population level will not sustain a viable industrial harvest, but would sustain a lower level harvest.

Perhaps the most efficient commercial utilisation of the kangaroo resources is achieved by the vocal non-users of kangaroo products. Whether or not the utilisation of the kangaroo is beneficial to the nation, there can be no doubt the effect on the sales of a firm will be beneficial if it can exploit emotion for promotion. This attitude appears strictly negative to me. What should be done to limit the damage kangaroos can do to the man on the land? What should happen to any kangaroos that are killed? etc. are all questions avoided rather than answered. If instead these non-users of kangaroos encouraged usage of the meat of the feral pig and goat, then they would be making a positive contribution to fauna conservation. It may be coincidence that the publicity to save kangaroos often comes from people who wish to substitute their product to satisfy the market at present using kangaroo.

The idea that kangaroos are not a utilisable resource, but are on the contrary one of the obstacles that have to be removed to achieve the maximum production potential of the land appears to be losing favour with many men on the land. Whilst it does not appear that any professional graziers yet regard kangaroos as an alternative crop, some graziers are showing greater willingness to co-exist with some kangaroos.

Arguments that kangaroos do not compete with domestic stock as violently as was thought earlier have led many graziers to a tolerance of some roo presence. Whilst now prepared to tolerate limited roo presence, graziers feel a need for provision of facilities which will hold the population in check and quickly remove pest kangaroos should these appear. These needs are catered for in New South Wales by the provision of Section 25 Licences to landowners able to establish that they are suffering damage. The recent decision in Queensland to reduce the number of registered chillers has had the effect of removing the kangaroo population control on which many graziers relied. Properties remote from the licensed chillers have to look elsewhere for relief from kangaroo competition.

Kangaroos and farming do not appear to be compatible. Farming demands the destruction of habitat and the protection of crops from pests, these needs leave little basis for co-existence. The survival of kangaroos in farming areas appears impossible unless some are retained in viable areas of habitat retained especially for the purpose. As I consider it unlikely that such facilities will be permanently provided, I expect kangaroos to disappear from agricultural areas.

No real attempt has yet been made by any significant grazing interests to fit the kangaroos into their production economics. Rather than making use of a crop deliberately planned and produced as part of a system of land use, the kangaroo has been removed to allow the introduced stock the fuller use of the land. It seems to me that if the man on the land is asked to live with more kangaroos, so that we city people can have our way, then it might not be unreasonable to assist him to fit the kangaroo into his economic system.

The commercial utilisation, in the normal sense, made use of the skins only, until in the mid 1950's when efforts were made to utilise the meat of the kangaroos.

The commercial collection of kangaroo skins was developed last century to provide raw material for a specialised kangaroo tanning industry which was established on the east coast of the United States of America. These tanners established a joint buying organisation which effectively controlled the industry until the development of the meat industry temporarily disturbed this control. The market for skins was successfully manipulated to prevent Australian tanners becoming established in the industry. The technical problems posed by the early skins produced from animals slaughtered for meat created a type of skin which did not appeal, at first, to the American tanners. An Australian tanning industry quickly developed in size and technical competence as a result of this new source of supply which appeared to be beyond the traditional control of the American tanners. The implications of this development were appreciated and efforts were made to recover control. Some of the early attempts were costly failures but as time went by techniques were evolved which overcame the earlier problems associated with the presentation and preservation of meat skins and the United States tariff policy assisted American tanners to hold Australian tanned skins out of competition with American tanned skins on the important American market. As another step in the recovery of control, interests were purchased in Australian meat processing firms. The Queensland Government recently ensured the recovery of control by these American tanning interests by making it virtually impossible for Australian tanners to obtain supplies of Queensland skins unless they obtained them from firms associated with the American tanning industry. Whilst I do not extol economic nationalism I do not consider it proper for an Australian Government to take action which denies supplies of raw materials to Australian industries, whilst making these available to industries located abroad.

The earliest attempts to utilise meat that I am aware of, used techniques and equipment adapted from the rabbit industry to produce a product aimed at human consumption markets abroad. The industry utilising the resource in this way was not able to retain the markets it secured because the Commonwealth

Government refused to provide the supervision of export processing that it provides for all other meats exported from Australia.

As a direct consequence of the Commonwealth Government's decision not to supervise export processing, the export of kangaroo meat has been erratic. This market instability resulted in the development of a significant local pet meat utilisation. This market developed rapidly as the meat's higher protein and low fat content made it a very popular pet food.

In recent years the industry has attempted to provide continuous supplies of fresh chilled kangaroo meat to the pet shop trade. Seasonal peaks of production have been used to supply the export markets, the canning trade, and to provide frozen stocks with which to supplement fresh chilled supplies during periodical seasonal production deficiencies.

My opinion is that it has been and will be the demand for skins which determines the quantity of kangaroos commercially utilised. It is not possible to process kangaroos profitably for meat unless the skins are marketed efficiently while it is quite possible, and normal, to process kangaroos for skins only. Moreover the market for skins has not shown any indication that it could be saturated by any probable production level, whilst the markets available for meat have never been adequate to utilise the meat of all of the kangaroos processed. Consequently kangaroo meat has always gone to waste; when meat markets are good less is wasted, when they are bad more roos are shot for skins and the meat allowed to waste. The last figures published in Queensland show that in 1965 not more than 35.65% of kangaroos harvested were used to produce meat.

Whilst the demand for skins establishes the number of kangaroos commercially utilised, the influence of the commercial utilisation of kangaroo meat on the distribution of shooting has been profound both in time and in space. Much of the meat market requires continuous supplies of fresh chilled meat. As a consequence kangaroo shooting for meat continues throughout the year whereas the skin industry formerly utilised skins shot during the cooler months only, for technical reasons which no longer apply.

It is necessary for the meat shooter to deliver his haul quickly to the refrigerated collection centres and in consequence meat shooters are concentrated within range of these facilities. This concentration of shooters has placed much greater pressure on kangaroo populations. The processing company, the transport operators etc. are able to achieve economies from this concentration process but the professional shooter finds it unprofitable and is usually replaced by a greater number of part-time shooters. Exploitation is more profitable than conservation. It should be the concern of responsible governments to ensure that it is not.

The experience of our Company in Queensland has shown that it is possible to reverse the concentration trend by employing fewer shooters at more places; by introducing more equipment in this way the harvest may be obtained without undue pressure being applied on the population at any one place. Reduction in the number of shooters in any area has other important side effects. It enables the professional shooter to continue to earn a satisfactory income, and in consequence he is able to become permanently located in one area. This lack of shooter turnover enables the landowner to have greater control over shooter behaviour and also enables him to depend on having an organisation locally available at all times to provide him relief from pest kangaroos should these appear.

Whilst it is possible to reverse the concentration of shooters it will not happen naturally. The firm which concentrates shooting enjoys economic advantages over the firm which does not and also appears able to capitalise on politicians' lack of understanding of the problem. Thus in Queensland, we see the Government, when advised that the concentration of shooting has done damage in some areas, solve this problem by furthering the concentration and removing firms which had reversed the trend.

There is also a belief in Queensland that concentration can do no real harm as it ensures that other areas will be freed from harvesting. I believe that the skin market has already demonstrated that its demand for other skins does not decrease as more meat skins are produced. The only control on harvesting in Queensland at present is the availability of shooters. The recent trend has been for skin prices to rise whilst other rural industries have become most unattractive income providers. My expectation is for the kangaroo harvest to increase, and this is in line with the Government's recently expressed view that the kangaroo industry should provide drought relief work. We have seen that by further limiting the number of chillers, the Government has concentrated meat shooters into still fewer areas whilst the intensity of shooting for skins is already known to be increasing in the other areas. My belief is that the type of control needed in Queensland should spread the collection as widely as possible, ensuring that, whilst landowners were protected, the harvest should not be excessive in any area. What needs controlling is not the number of chillers but the number, species and location of kangaroos shot.

There is ample evidence that this concentration of shooting has resulted in the level of harvest in some areas already having been so high that populations have gone into decline. This has given rise to a fear that the industry will shoot itself out of business and to requests that Governments intercede. The State Governments do have the power to control how many kangaroos will be shot—where, when and by whom. It seems to me, however, that their exercise of this power depends on the intention they have for the kangaroos in their charge. Whilst the policy of the N.S.W. Government appears to be to limit harvesting sufficiently to allow population recovery, the Western Australian government until recently classified most kangaroos as vermin. The policy of the government in Queensland, whilst proclaimed to be conservation-orientated, appears to me to be intent on achieving as rapid a reduction in the kangaroo population as possible. To achieve this, firms with population stabilisation policies have been removed to make access for firms with greater efficiency in kangaroo population reduction. This policy will probably be reversed when, as with koalas, the population level becomes acceptable to the Government.

I believe that in the immediate future, the harvesting of kangaroos should be regulated to achieve a stable population below pest level. Whilst temporary provisions should be available to allow relief from pest kangaroos I believe it important that the tendency to concentrate shooters should be checked and reversed. This could be achieved by regulating the issue of shooters' licences in sympathy with the issue of permits to shoot.

The quantity of kangaroos to be shot should be calculated and regulated with the best procedures available, to take off the net increment to the population. The results of the harvesting on populations should be studied to determine harvesting policies for the following periods. This policy could be applied right now but would soon expose new directions for research which would, I hope, be accepted. For such policies to work requires adequate staff to determine and to enforce policy, and for research, and requires co-operation between the authorities in the various States.

In the very near future, I would hope to see the Commonwealth Government exercise control over the processing of kangaroo meat for export. I believe this would reduce the tremendous waste of kangaroo meat that still goes on, would up-grade the industry and could eventually lead graziers deliberately to produce kangaroos as a market crop.

I would also hope to see the Australian tanning industry provided with an opportunity to obtain supplies of kangaroo skins. I do not suggest that American tanners should be denied supply but I feel it is most improper for them to be guaranteed supplies by preventing Australian tanners from competing with them for supplies.

In conclusion I hope that you will agree that there is a place for the commercial utilisation of kangaroos; and that it is agreed that the exercise of control is necessary and must be provided, at least until kangaroos are assimilated into the grazing economy

I consider it an inevitable consequence of human influence on the environment that some areas will be cleared of kangaroos. Whilst recognising this to be inevitable, in some places, I feel that the extent of these wildlife deserts should be limited. The view held in Queensland, that the regulation of harvesting there is adequate because it ensures the survival of pockets of kangaroos, appears to me to be bad husbandry. Kangaroos are a part of the environment which could be retained in most areas if positive motivation existed. I believe that a properly regulated industry could provide this motivation.

People who oppose the commercial utilisation of the nation's kangaroo resources have an obligation to convince us that the survival of the species would be assisted by non-utilisation. They are aware that kangaroos will be shot or destroyed and, in advocating that meat or skins not be used, they are advocating the waste of the resources of the nation.

MANAGEMENT OF KANGAROOS

by G. B. SHARMAN
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(Figure 1).

This paper is about three of the larger species of kangaroos—the red kangaroo (*Megaleia rufa* Desm.), the eastern wallaroo (*Osphranter robustus* Gould) and the eastern grey kangaroo (*Macropus giganteus* Shaw). Where necessary comparisons are made with other macropodid marsupials all of which are included under the collective name "kangaroos". Some aspects of kangaroo management, considered essential knowledge if domestication on a large scale is to be attempted, are dealt with and comparisons are made throughout with the domesticated sheep.

REPRODUCTION

Management of kangaroos depends on knowledge of the reproductive processes involved in natural increase. This is evident from the attention, given by earlier speakers in this Symposium, to ecological aspects of reproduction.

In the three kangaroos with which I am concerned the gestation period, here defined as the period of continuous development of the embryo between fertile mating and birth, is shorter than the length of one oestrous cycle. This is generally true of marsupials (Sharman, 1970).

The life of a female kangaroo may be divided into five phases (Fig. 1), the first of which is the period between its conception and its birth. This interval, provided that the mother is neither lactating nor in some other environmentally determined non-breeding phase, is about 33 days in the red kangaroo (Sharman & Calaby, 1964), 35 days in the eastern wallaroo (Kirkpatrick, 1968) and 35 to 38 days in the eastern grey kangaroo (Kirkpatrick, 1965a). The newborn kangaroo, not being equipped for the semi-independent existence characteristic of many newborn true mammals, is suckled in the mother's pouch while completing embryonic development (Phase 2, Fig. 1). Pouch life lasts about 8 months in the red kangaroo (Sharman, Frith & Calaby, 1964), 8 to 9 months in the eastern wallaroo and 10 months in the grey kangaroo (Kirkpatrick, 1965b). After emergence from the pouch the young of each species spends several months suckling from the exterior, followed by a non-suckling period during which it may be closely associated with its mother (Phase 3, Fig. 1). Females of the three species of kangaroos may become sexually mature when 16 to 18 months old (17 to 19 months after conception—Fig. 1). Parturition after the first pregnancy (Phase 4, Fig. 1) completes one major reproductive cycle, female kangaroos being potentially capable of producing their first replacement 18 to 20 months after their own conception.

Oestrus, ovulation and fertilization occur just after parturition in the red kangaroo, eastern wallaroo and in most other kangaroos. In the eastern grey kangaroo, and in at least one other species, fertilization usually occurs during pouch suckling, between 4 and 8 months after parturition. These reproductive patterns are generally characteristic of kangaroos, exceptions being the swamp wallaby (*Wallabia bicolor* Desm.) which is fertilized just before parturition (Sharman, Calaby and Poole, 1966) and the western grey kangaroo (*Macropus fuliginosus* Desm.) in which no unequivocal case of fertilization during pouch suckling has yet been demonstrated (W. E. Poole, pers. comm.). In those kangaroos in which fertilization occurs just before birth, just after birth or during pouch suckling, the derived embryo enters a period of dormancy, called embryonic diapause, while the earlier young is suckled in the pouch. The fate of the dormant embryo varies from species to species. In the quokka (*Setonix brachyurus* Quoy & Gaimard) it is available to replace young of wild animals lost during the breeding season, but degenerates thereafter (Shield & Woolley, 1963), whereas in the tammar (*Macropus eugenii* Desm.) the

dormant embryo is retained during the five-month non-breeding period from August to December and becomes the first young of the new breeding season in January (Berger, 1966). In the kangaroos considered in Fig. 1, breeding may be continuous so that Phase 5 is repeated until death of the animal. As each young leaves the pouch it is replaced by a young derived from the hitherto stored embryo so that suckling of the just-emerged young is accompanied by suckling of a new young in the pouch.

Before considering environmentally induced modifications of breeding patterns in kangaroos, it is instructive to compare breeding rates in a domestic herbivore (the sheep) with that of the red kangaroo. In the red kangaroo the period of lactation in the pouch sets limits to the breeding rate because two young cannot occupy the pouch together even though breeding is continuous. The female, throughout a long reproductive life, can thus produce young at the rate of one each eight months, or three young in each two years. In some types of sheep the shortness of the breeding season limits lamb production to one per year but in others the occurrence of two breeding seasons per year, or continuous breeding throughout the year, allows a reproduction rate equal to that of the red kangaroo.

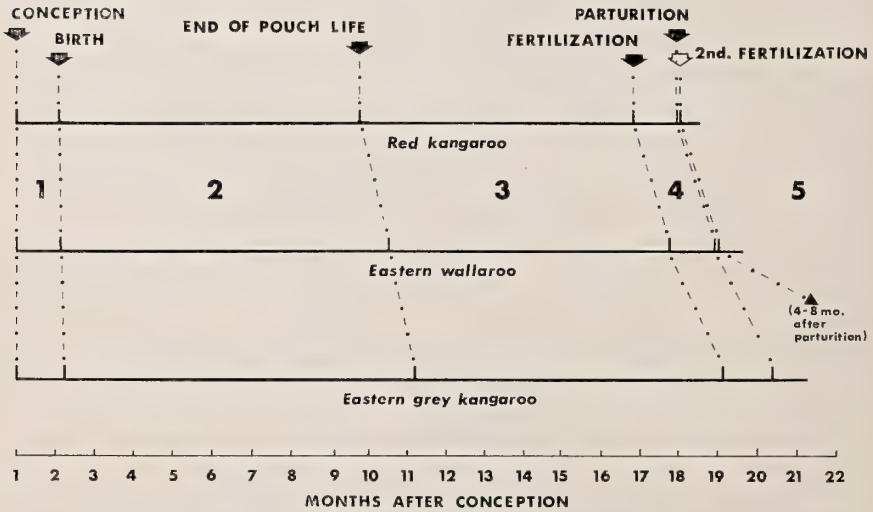

Figure 1.—Life history of kangaroos. 1—Period of gestation in mother's uterus. 2—Period spent in mother's pouch. 3—Period spent suckling from exterior of pouch and as juvenile. 4—Pregnancy. 5—Period spent suckling successive young in pouch.

It has frequently been asserted that native herbivores are better adapted to environmental conditions in their natural habitats than are the prevailing introduced herbivores, and wild animal farming has therefore been suggested for marginal pastoral areas. During the frequent droughts which occur within the 20 inch rainfall isohyet of Australia (the area occupied by the red kangaroo) sheep are either moved elsewhere or prevented from breeding. During drought, breeding ewes may contract pregnancy toxaemia—a generally fatal disease. If pregnancy is successfully completed during drought the lambs frequently die. Kangaroos do not suffer from pregnancy toxaemia, indeed, once initiated, pregnancy usually proceeds to term; the short gestation period and small neonatal size of kangaroos freeing the mother from the ills which may afflict the pregnant eutherian.

However drought affects the breeding cycle of the red kangaroo at stages other than pregnancy (see paper by A. E. Newsome, this Symposium). My results come from the study of a population of red kangaroos at Wilcannia in western New South Wales during the drought which began in September 1963. The population had been studied during the previous four years (Frith & Sharman, 1964), and at the beginning of the drought nearly 70% of females two years old and older had young in their pouches. An early effect of drought was the death of advanced pouch young. Emaciated, dying and dead young were found in the pouches and evidence of recent death of young was obtained from the high incidence of females, not accompanied by pouch young or young-at-foot, which had elongated teats, indicating recent suckling. Two years after the drought began only about 30% of females were carrying pouch young. Twenty to 25% of females two years old and older were suckling young-at-foot when the drought began, but virtually no young-at-foot were present two years later. Many females which lost pouch young gave birth to another derived from the dormant embryo but these young also died: deaths occurring at successively earlier stages of pouch life as the drought progressed. Failure of effective breeding was not entirely due to deaths of young. Some females failed to exhibit post-partum oestrus and ovulation (Newsome, 1964; Sharman & Clark, 1967) and remained in anoestrus following loss of their young. Young females failed to begin breeding at the expected time and did not reach breeding condition during the drought. Thus the number of females capable of breeding fell from 90% at the beginning of the study to less than 30% after two years of drought.

Failure of effective breeding during the drought eventually resulted in there being no red kangaroos less than two years old in the Wilcannia population. Since commercial shooting was not taking place on the sheep station where the study was carried out, it is relevant to enquire how much the present low population numbers are due to past failure of effective population replacement. Shooting has been widely blamed for the decimation of the red kangaroo but weather conditions must be in part responsible. The Wilcannia drought effects were not, however, due to shortage of water as such: all kangaroos had access to adequate water in station troughs and many had access to the Darling River. Newsome (1965) earlier showed similar, or more severe, drought effects on breeding in central Australian populations of red kangaroos.

Drought management of sheep involves moving them to better grazing or hand feeding. Only the second alternative is available for drought management of kangaroos.

GROWTH AND MATURITY

Tribe & Peel (1963) found that over half the body weight of red and grey kangaroos is due to carcass muscle—in other words, more than 50% is useable as edible protein. The amount of carcass muscle in domestic animals varies between 27% (sheep) and 32.6% (cattle), but wild ungulates may have up to 46% carcass muscle. They suggested that, "in view of its body composition—the value of the kangaroo as a producer of edible protein in areas marginal for production of domestic livestock, is worthy of investigation". However, figures for yield of edible protein are meaningless unless growth rates are also taken into account. The red kangaroo reaches sexual maturity when about 520 days old at a body weight of about 35 lbs., the sheep at 460 days old at a body weight of 85 lbs. (Table 1). At this time the two herbivores yield approximately equal amounts of edible protein at about equivalent ages. A red kangaroo takes at least 6 years to reach full size and yields only about an equivalent amount of muscle to a sheep less than 2 years old. The red kangaroo, the longer lived animal, has the slower rate of growth, a factor which has to be taken into account if production management of kangaroo is envisaged. Perhaps the slow growth rates of kangaroos are a reflection of the generally low metabolic rates of marsupials, Dawson & Hulbert (1969, 1970) having shown that the marsupial level of metabolism is approximately 30% lower than that found for eutherians.

TABLE 1.

Body weights and total muscle weights of red kangaroo (*Megaleia rufa*) and sheep at various ages.

Stage of life cycle	Red kangaroo ♀			Sheep ♀		
	Days from conception	Weight (lbs.)		Days from conception	Weight (lbs.)	
		Gross	Muscle		Gross	Muscle
Birth	33	0.022	—	148	10.75	2.9
Sexual maturity	520	35	18.1	460	85	22.9
Full size	2190 (6y.)	60	31.0	610	120	32.3
Maximum age	9125 (25y.)			5475 (15y.)		

FEEDING

Kangaroos, being pseudo-ruminant herbivores, are well adapted to the generally arid interior of Australia where much of the available food is of a fibrous nature. Foot & Romberg (1965) concluded that the red kangaroo was better adapted to making use of very poor roughage than the sheep. McIntosh (1966), however, found that digestibility coefficients for both lucerne and oaten chaff were higher in the merino sheep than in the red kangaroo and that sheep appeared to retain nitrogen more efficiently than kangaroos, particularly when the intake of dietary nitrogen was at a low level.

Griffiths & Barker (1966) found no evidence that, pound for pound body weight, kangaroos eat more than sheep. In a field study of the plants eaten by red and grey kangaroos and sheep grazing in the same paddock in south-western Queensland these authors found considerable differences in the dietary intake in the three species. Kangaroo stomachs always contained green herbage whereas those of sheep contained mostly dried-off herbage. Red kangaroos and sheep ate a mixture of about 46% grass and 54% dicotyledons whereas greys ate 64% grass and 36% dicotyledons after good rainfall and lush pasture growth in January. As the pastures dried off, the intakes for red kangaroos and sheep became 68% grass and 32% dicotyledons and for grey kangaroos 79% grass and 21% dicotyledons. Over a period of one year, considerable differences in intake of nine major food plants were evident. Mulga (*Acacia aneura*), a tree with a relatively high protein content, was extensively eaten by sheep but not by either species of kangaroo. Plants of the family Malvaceae, especially *Hibiscus stuartii*, were frequently eaten by sheep but formed a very low percentage of the diet of kangaroos. *Portulaca oleracea* and the grass *Themeda australis* (appropriately called kangaroo grass) were favoured by both sorts of kangaroos but hardly touched by sheep. The authors concluded that food preferences were specific enough to justify the conclusion that the plants of the habitat and the three species of animals constituted an ecosystem.

KANGAROO "FARMING"

I have not considered reproduction or feeding of domestic kangaroos. Feeding is simple—kangaroos in captivity can be fed similarly to sheep. It is conceivable that by application of known techniques, including selection at an early stage of pouch life for desired sex, hormonal induction of oestrus and ovulation, increasing the production of good breeding stock by foster-mothering their young, artificial selection, attention to nutrition, etc., a domestic population of kangaroos could be economically viable. Kangaroos are, however, difficult to handle and do not yield a wool clip once a year, so it is unlikely that return above running costs would be greater than for sheep or other domestic animals, a point of greatest importance considering the present difficulties of the small farmer. At least one of the important diseases of confined kangaroos—lumpy jaw—must be overcome before intensive domestication is considered. The disease is responsible for 30 to 47% of deaths in kangaroos in zoos (Barker, Calaby & Sharman, 1963); treatment calls for extensive surgery and expensive antibiotics and is by no means completely effective.

Until a well-controlled pilot experiment has been carried out with domestic kangaroos, it appears better to exploit kangaroos by a rangelands programme. As the diets of red kangaroos, grey kangaroos and sheep are to some extent different it is possible to conclude, as did Dr. M. E. Griffiths, that these "three kinds of animals and the plants of their environment, are equivalent to the ecosystems established by the great herds of herbivores in central and east Africa. In such systems there is greater utilization of herbage so that more of it is turned into animal protein at any one time if several species graze together, than if one species alone grazes" (quoted by Sharman, 1967). The statement, "Once you ranch fur, you remove the danger of upset to the balance of nature", attributed to the Chairman of the Fur Trade Association of New South Wales (*Australian*, June 25, 1970) is, unfortunately, not relevant to the theme of rangelands management of kangaroos. It is likely that the relative

abundance of the larger kangaroos in sheep country is a result of upsetting the so-called "balance of nature" and that the kangaroos would begin to disappear if the sheep were removed.

If the present policy of giving permits to shoot kangaroos when they reach high numbers can be called a rangelands programme, then the minimum-size regulations for red kangaroos in New South Wales should be revised. The present regulations forbid the shooting of smaller animals which have not bred, but allow mature females, thought to have bred at least once, to be shot. The regulations thus ensure that for each four females shot during good seasons at least three pouch young are killed and one young-at-foot faces possible death by starvation. With each of the females carrying pouch young removed from the population, the dormant embryo—a future kangaroo—is also removed. It would be far better to take, for conservation, humane *and* productivity reasons (see Table 1), the juvenile animals up to 35 lbs. weight and the largest animals; it being known that fecundity and fertility are reduced in aged kangaroos of both sexes.

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DISCUSSION

Rapporteur, Mr. J. M. Smail:

SMAIL: A question from the floor:

At what stage of pouch life of a young kangaroo does implantation of the embryonic blastocyst stage take place? and what is the stimulus for this implantation?

SHARMAN: This question, of course, depends on the species of kangaroo. I take it the questioner was talking about the larger sorts of kangaroos—although iit's questionable whether a kangaroo embryo ever does implant because there is no close association between the uterus and the embryo. The dormant blastocyst begins to develop at a stage of pouch life which is nicely timed so as to allow the young to get out of the pouch just before the new young, derived from the stored embryo, is born. In other words, the red kangaroo can in the space of one day rid itself of its young in the pouch, give birth to another young, and then copulate again and get an egg fertilised which is going to become the next stored blastocyst. While the embryo in the pouch is small it suckles virtually continuously and development of the stored embryo does not occur. Towards the end of its pouch life it is suckling intermittently. Even though it is taking more milk it is drinking much less often, and at that stage the stored embryo begins to develop. This can be tested experimentally by foster mothering an extra young so that the teat is stimulated for twice the length of time, and under these conditions development of the stored embryo does not always occur. In other words, if you increase the stimulus of suckling you can keep the stored embryo delayed a little longer.

ROBERTS: While the majority of Australians wish kangaroos to flourish, a condition which can cause loss and damage to some graziers, do you favour Government subsidies for those graziers who can prove that kangaroos are affecting their livelihoods?

SMAIL: Let me add a related question from the floor:

What payment does the grazier receive now for the acknowledged threat to his property, and could not this factor be adjusted to provide incentive to both grazier and commerce in developing long term kangaroo management?

DOOHAN: In answer to the first question—it's something that I have never considered but I think the answer would be no. I say that without much consideration because I'm not all that in love with subsidies. I think that there are other more effective measures that can be taken to make industries more profitable probably than through the use of subsidies, but bear with me—I haven't had much time to think of that. As regards to what does the grazier now get for kangaroos, the answer of course is nil, unless he takes them himself and gets payment for the meat and the skins. But largely it's taken by the trade and he is not compensated. I think Dr. Frith touched on this earlier.

JONES: What research has been carried out by the graziers in relation to kangaroo management, as pests and so forth?

DOOHAN: There has been no research carried out by graziers themselves. Graziers are not research people but they have contributed substantial amounts of money towards universities and other bodies to aid research.

JONES: A question to Mr. Livanes:

How does one successfully manage an animal population without knowing the fullest details of populations? To conserve essential breeding stock it is necessary for all the details to be known.

LIVANES: It is not possible to have the 'fullest details' of animal populations. We have to decide what to do with less knowledge than we would like; it is not possible to say that we will do nothing because we need more knowledge. Doing nothing has considerable effect on animal populations.

We do have a responsibility to add to our knowledge so that we may realise, as fully as possible, the consequences of what we do. The need for more information is urgent. If it were provided immediately the cost would have to exceed the probable return for quite a long time into the future. We have therefore to increase our knowledge as quickly as we can afford to, ensuring in the meantime, that we do not allow the use of the resource to be so great that the resource is mined away.

The regulation of the industry's usage of the resource is based on inadequate information. Most States now ensure that harvesting levels are kept lower than is necessary for population equilibrium. The future will probably see a system of regulation based on knowledge; if it does it will remove many of the current problems.

Question from Mr. Ray Sherry, M.P., of the Select Committee on Wildlife Conservation, House of Representatives:

SHERRY: The academics and the practical grazier seem to be in conflict apropos the competition between the domestic animal and the kangaroo with regard to food. Is this a perennial argument between academics and laymen and if so, how do we resolve it and convince the general public who is right and why?

SHARMAN: Nobody is right because no scientist will say that kangaroos don't compete with sheep. Kangaroos are grass-eating animals, and this goes back to Dr. Ride's comments that they probably evolved during or soon after Miocene times when the grasses became abundant. Kangaroos and sheep do compete. If I could now quote briefly from Griffith and Barker's paper we find firstly that kangaroos eat no more than do sheep. I think that's generally agreed. Red kangaroos and sheep ate a mixture of about 46 per cent grass and 54 per cent dicotyledons whereas greys ate 64 per cent grass and 36 per cent dicotyledons after good rainfall and lush pasture growth in January. As the pastures dried off the intakes for red kangaroo and sheep became 68 per cent grass and 32 per cent dicotyledons and for grey kangaroos 79 per cent grass and 21 per cent dicotyledons. Some examples of food preferences of kangaroos and sheep are given in my paper to this Symposium. I suspect that as times got hard—most of these studies, unfortunately, were done during comparatively good seasons—the sheep and kangaroos would come to compete more for the available feed than during good times. Now during hard times the kangaroos are taking their own measures, if you like to put it that way, because without the green feed which Mr. Doohan referred to they cannot breed and their reproduction rate falls off. But I don't think this is a matter of conflict between the graziers and the academics or between the laymen and the academics at all. Finally—if you are to start a rangelands programme for kangaroos you must realise that kangaroos and sheep don't completely overlap in their diets. They have some differences and a better return may be had by exploiting both sorts of herbivores than by exploiting sheep alone and attempting to eliminate the kangaroo.

MacQUEEN: Does Mr. Doohan have knowledge of any property in the western part of the state that would stand an inspection at the present time to substantiate a kangaroo pest claim?

DOOHAN: Most of my remarks weren't in regard to the present. There's no doubt that the drought has had a very significant adverse effect on kangaroo populations. I am not able to name a property for Mr. Macqueen, it is not my function to inspect other properties, but I am aware that there are properties that are carrying an unreasonable population of kangaroos at the present time. My property is not.

SMAIL: One other question from the floor to Mr. Doohan:

Do you consider that there is any substance in the argument that the kangaroos are blamed for damage actually caused by sheep or poor property management?

DOOHAN: Speaking generally, I'd say the answer is no—no foundation for it.

SHARMAN: I don't think there is enough knowledge about kangaroos to base an industry on them, as Mr. Livanes wants to do. I should also like to point out that the kangaroo industry is worth peanuts compared to other primary production—and that's a brutal fact. No Government will spend the amount of money required to do the sort of surveys which Dr. Newsome did in the Northern Territory and Dr. Frith did in western New South Wales in order to find if kangaroos are abundant enough to be exploited. This calls for expensive equipment, high skill and accurate counts of kangaroos. In spite of the quite enormous areas covered by Dr. Newsome and Dr. Frith, these are just a microscopic part of the total range of the red kangaroo. It might be better to conclude that the kangaroo industry isn't worth supporting and that, if it is necessary to destroy pest animals, they should be left to rot where destroyed. Whatever they have in their bodies is then returned to the soil from whence it came.

RIDE: The alternative to gaining expensive biological data might be to do what graziers have long done in the management of populations of sheep and cattle, (and the medical profession have done with human ills) that is simply to treat the symptoms. Now, the barrier we have here in Australia to the responsible utilization of fauna by landholders (as a result, I believe, of the attitude of the colonists to the obnoxious nature of the penal system in the United Kingdom, particularly in relation to poaching), is that our laws make sure that no landowner owns the wild fauna that runs on it. The remedy may be to place the rights to kangaroos in the hands of people who hold the land and give them the responsibility (and economic advantage) of obtaining a crop which is a balanced crop of both kangaroos and of domestic stock. By doing it in this way we might provide some incentive to the grazier to treat the symptoms and actually to crop the populations as a resource. I only make this as a suggestion for discussion; whether or not graziers, in general, would be sufficiently responsible to take advantage of the mixed crop I don't know; but it might be one way of dealing with the problem.

DOOHAN: I think this is an interesting subject but I certainly agree with Dr. Sharman—I don't think any of us know enough about it. The objective is probably a good one but there are certainly a lot of obstacles. First of all, the thought of running kangaroos as a second or a third type of stock would seem to me to have some merit on some properties—and I say "some properties" because every property is different. If I were going to buy a property in the country I would want to have a look and decide whether I was going to run sheep or cattle or both, and it so happens that on my Wanaaring property I have both because I think that with the two I can get the full value of the feed. They are competitive in some types of feed but not all, and I think it would be reasonable to think that kangaroos would be a third one that would be competitive in some areas and not in others as far as feed is concerned. The problem of farming them is something that has been talked about. At present the farmer or grazier gets no return from them. He owns the land, he has paid all the rates, he is liable for all the costs, and if you expect him to have a big population sufficient for an industry, he bears the loss but has no profits. If you decide that he should

have a profit, then you have to decide which are his kangaroos and which his neighbour's—and this is a problem. The main part of the pastoral zone of this country is not fenced for rabbits and it does not stop kangaroos. It would be expensive to put fences in to stop kangaroos: and if you did, I really don't believe that they'd survive in a drought as well as sheep do. They survive because of their flexibility—they are able to move about, and if you took that away from them, they might do as well as cattle but not as well as sheep do. And this is all-important in the dry areas.

STRAHAN: I would like to point out one of the outcomes of Professor Sharman's remarks. I am not saying anything new but putting it perhaps a little more strongly than he did. The idea of kangaroo farming which is being discussed by some conservation-minded people has been shown by these figures to be completely impracticable. The only reason that there is money to be made out of kangaroo flesh at the present moment is that kangaroos are dirt-cheap; they cost nothing. It is not a popular meat, but you can sell it because it does not cost you anything. If you want to farm kangaroos they would become costly. Professor Sharman said the trade is "worth peanuts". I think it probably is on any national scale, but I would like to direct a question to Mr. Livanes in the hope that he may have some knowledge of this. What is the national income from meat and from hides at the present time?

LIVANES: I'm afraid I could not answer that question. I could provide an answer for you 15 minutes after I arrive home, but I would rather not take a stab at it.

SHARMAN: Mr. Chairman, I spent a considerable amount of time trying to get this information from the 1969 *Commonwealth Year Book*. I could not find any information there. It is negligible compared with the other meat and hide exports from Australia.

SMAIL: Mr. Doohan has made the point that the kangaroo is in fact in many areas a pest, but that the grazier does not wish to see it disappear as such, and is prepared to tolerate it in reasonable numbers. Questions have been raised as to whether the kangaroo can be farmed or not, and apparently the balance of opinion seems to be that it is not an economic proposition. Mr. Livanes has made out a case for a kangaroo industry which has been contested to some extent, as regards its national economic importance, by Professor Sharman. And it would appear that one of the factors involved is the lack of knowledge that we have of the actual ecology and status of the kangaroo.

FOURTH SESSION: CONSERVATION OF KANGAROOS

KANGAROOS AND THE GENERAL PUBLIC

by VINCENT SERVENTY

I am here to put forward the views of the man-in-the-street, the average person who has been making such a clamour lately about the fate of the kangaroo. It would be a brave man who would be willing to speak for such a varied group, which ranges from those with religious views on the taking of any animal life, through to scientists and business tycoons who feel angry about what they hear of kangaroo slaughter. In terms of knowledge these same people vary from those who know only one species *'The Kangaroo'* to those who have an intimate knowledge of the various species of kangaroo. With this diversity all I can do is put what I think are the viewpoints of the majority of this army of conservationists. Many belong to organisations, which have been bombarding the politicians of late. Many have no organised voice. From my position as Editor of *Wildlife in Australia,* running a newspaper column, giving lectures and appearing on television, I am on the receiving end of thousands of letters, phone calls and personal interviews each year so I have some feeling for the general pattern of interest. I can say without hesitation that most Australians are not satisfied with what is being done in the cause of kangaroo conservation. Justice must not only be done but be seen to be done. The kangaroo may be in no danger of becoming actually extinct but in may become visually extinct everywhere.

Do not make the mistake of dismissing the public as 'amateurs' and 'emotional'. Both statements need examining. As to amateurs, there are very few professionally trained conservationists in Australia, if any. New courses at Armidale and Canberra will redress this balance. Most of us picked up our varied skills as best we could, some building on the foundations of an academic discipline. A knowledge of marsupial protein, or kangaroo farming, or public relations, or economics does not make one a conservationist. Yet these are all facets of the story and we need to know something of many fields. There are no amateur and professional, only good and bad, competent and incompetent conservationists.

We now turn to emotional. Some scientific friends of mine are not worried by changes of habitat or the introduction of exotics, or the extermination of species. All these are interesting and can be studied as problems. No doubt some could observe the destruction of the human species with the same detachment. Fortunately most of us don't hold these views. Scratch most conservationists and underneath you will find one who enjoys wildlife for its own sake. The emotional thrill may be from seeing a bowerbird display, a coral reef, or Big Red bounding over the inland plains. Emotion is the spur to action. One of the opposites to emotional, is unfeeling or apathetic. That is not a cap I am willing to wear.

Let us look at the controversy historically. First we have an analogous case with the Great Barrier Reef. Some years ago there was an application to mine Ellison Reef. The opposition to this mining came basically from the Queensland Wildlife Preservation Society and the Littoral Society. There was little organised scientific interest and it looked like a case of David and Goliath.

David in this case was psychologically unaware of his strength and at first was willing to compromise on the mining aspects to the extent of allowing oil exploration. But the arrogance and greed of mining interests and Governments stiffened his resolve. The societies took the extreme position—no

mining on the Reef. To everyone's surprise, except the societies concerned, they won the fight, at least for the present.

I can see the same pattern of anger building up on the kangaroo question. There will soon be a clamour for a moratorium on all kangaroo shooting in Australia. It has not come yet because the major conservation societies have not been committed to the public battle. If they become angry because of the greed of the industry or the apathy of Governments, they will take that extreme position. And they have some potent weapons:

1. There is the possible ban on all kangaroo meat and skin exports. This can be enforced by the Federal Government.
2. There is the possibility of the public boycott of all goods containing kangaroo meat or fur. Even a ten per cent boycott can make a difference.

I would dislike this to happen as I feel such an extreme position would be harmful to kangaroo conservation in general.

Historically we have had many warnings about the kangaroo position. Professor Wood-Jones, Ellis Troughton, Neville Cayley, David Stead and a host of others have been warning us of dangers facing our wildlife and the environment. All this groundwork has helped today's interest in conservation. More particularly it must be remembered that a love of nature is no inborn emotion of the human race. It is something slowly acquired as we progress towards a more sensitive and mature attitude to the natural world. If we think of sophistication in the modern meaning of the word, something acquired through a variety of influences, then the intensity of one's love for nature is a measure of one's sophistication.

It is obvious that millions can live and die without having any feeling for nature. Every kangaroo could be slaughtered and they would not lift their eyes from the trough. It is also true that millions of people only lead half-lives, never functioning fully as man has the potential to function. Accepting that this slow education has produced some results, the sudden outburst of interest is part of a world-wide pattern among urban man. The feeling of urgency has come from the present slaughter in terms mainly of the meat trade. TV and newspapers have brought the slaughter vividly home to us.

Of course the Aborigines hunted the animal and Norman Tindale estimated they may have taken about 176,000 animals a year. The white man assisted in this hunting and Charles Darwin in 1836 was invited on a hunt and wrote 'We continued riding the greater part of the day but had very bad sport, not seeing a kangaroo or even a wild dog'.

Despite all gloomy predictions the larger kangaroos survived. A new factor came in because man's grazing animals and other changes helped the kangaroo to increase.

Then came the holocaust of the fifties and sixties as hunting turned from rabbits to kangaroos for meat and fur. In 1960-61 6,163,493 lb. were exported with in 1966-67, 8,532,937 lb. Last year there was a dramatic drop to 2,223,237 lb. At present a million kangaroos are taken each year in Queensland alone.

An interesting item is that the greatest clamour has come from Victoria, one State where the controls are adequate. In other words we have now become Australia-minded and no longer parochial in wildlife conservation.

The result of this hunting is that from the average person's point of view the kangaroo is now extinct. Nowhere can the average person see a live kangaroo within convenient distance of urban areas. Many tourists have complained of travelling around Australia without seeing a kangaroo. Even scientific parties have made similar complaints. It is no good saying that people don't see kangaroos because they only come out at night. When kangaroos are common and not hunted they will graze throughout the day

in winter and in the morning and late afternoon in summer. For the average Australian any population of kangaroos which is hunted has become visually extinct. He will not be satisfied with census figures which indicate there are still kangaroos in the bush. As far he is concerned they are gone.

When we consider that outdoor recreation is our fastest growing industry and that tourism is at present the world's biggest industry in terms of economics the kangaroo is big business. For it is koalas and kangaroos which bring tourists to Australia. If the kangaroo becomes extinct we will suffer a severe economic loss which makes the present few million dollars earned by skin and furs a mere flea-bite.

What action would satisfy the general public?

1. A system of national parks basically for kangaroo conservation, though of course they would have other attractions. Five per cent of our area is the minimum figure suggested for national parks. Over most of Australia the figure is between one and two per cent so there is plenty of room for expansion. There are only a few national parks where one can see red kangaroos at present and most are in outback areas. So a chain of national parks in good kangaroo country is urgent. At the present rate New South Wales will achieve its five per cent aim in another seventy years yet this State leads in the national park movement.

Barrow Island in Western Australia has a population of euros at 50,000 acres so this must be a minimum size. To be on the safe side we need at least 100,000 acres and this should be the aim.

2. There should be more work on multiple use of farms. Tax encouragement should be given to those who want to keep natural bush. At present the reverse holds.

3. There should be encouragement given to farms for kangaroos and sheep. We know that sheep numbers must be dropped in many areas to save the country from degradation. The loss in income could be made up by cropping kangaroos. Yet the Federal Government refuses to provide the money needed to purchase a station property to test the economics of such a proposal. Wild game ranching is being carried out in Africa and Russia. The parrot cry of 'we need more research' must not be allowed to stand in the way of trying out the experiment.

4. From this stems the new idea that kangaroos should be regarded as the property of the man who owns the land. This has been suggested for crocodiles. Once a farmer begins to regard kangaroos as his property he will take care they are cropped, not mined. At present kangaroos do him no good and despite all research findings he feels they are doing him economic harm.

5. More rangers. There are always hooligans and only more rangers will keep these in control.

Above all we must act quickly so that the kangaroo, the symbol of Australia remains as a widespread wild animal all over Australia.

PRACTICAL ASPECTS OF KANGAROO CONSERVATION

by D. F. McMICHAEL
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(Figure 1.)

The kangaroo can jump incredible,
He has to jump because he's edible,
I could not eat a kangaroo,
But many fine Australians do.

—Odgen Nash.

The policies and practices presently in force in New South Wales have evolved over the years as a result of the experience and consideration of the former Fauna Protection Panel and the then Chief Guardian of Fauna, Mr. Allen A. Strom, and more recently from investigations made by Mr. Allan M. Fox, Chief Wildlife Officer of the National Parks and Wildlife Service, and the Assistant Director (Wildlife), Mr. W. S. Steel. My task is to present the background to these policies, and to outline some of the practical problems facing those who are administratively responsible for the conservation of kangaroos in New South Wales.

As an administrator charged with the dual responsibility of conserving wildlife and ensuring that some relief should be given to those affected by wildlife in pest proportions, I wish to make two basic propositions which are essential to the approach of this paper:-

First, that kangaroos are at times, in some places, sufficiently numerous to qualify as pests and that it is justifiable to permit reduction of their numbers.

Second, that it is wasteful to permit the destruction of a resource without taking steps to utilize to the maximum extent that proportion which is destroyed.

On these bases, the managed cropping of kangaroo populations and the commercial exploitation of the skins and carcases can be accepted as proper conservation. The alternative propositions that kangaroos should be allowed to fluctuate in numbers regardless of the effects on other resources, and resource users, or that the animals, when killed, should not be utilized makes no sense to me, either biologically or rationally, and will not be further considered.

The managing authority in this situation is faced with a number of practical, legal and political problems which have not yet been fully resolved. This paper will outline some of these problems, and indicate what management techniques have been or are about to be adopted in New South Wales to resolve them. I will also outline some new techniques and management procedures which are being explored for the future.

PRACTICAL PROBLEMS

The most pressing practical problem facing the management authority is to determine population size and cropping rates which are acceptable both biologically, economically, and aesthetically. Obviously we are not dealing with enclosed, discrete populations on particular properties which can be counted and managed without reference to neighbouring lands. The kangaroos are a shifting group of animals, sometimes organized into discrete interbreeding populations which could be treated in isolation, but more frequently dispersed over a wide area, occasionally forming into mobs, and moving from place to place.

J. W. Winter has suggested (see Ratcliffe, 1970) that to maintain a steady cropping rate, approximately 5/6ths of any population should be left each year to replenish numbers. But, obviously in order to establish a balanced situation, it is necessary to have two basic pieces of information:

(i) What numbers of kangaroos are actually present in a given area,
(ii) What is the pattern of distribution.

The former is necessary if one is to limit the off-take to about 1/6th of the total population, while the latter is necessary to determine from which properties these should be taken.

Unfortunately, if the bulk of the kangaroos in an area are in a mob on one property, that particular property owner is not going to be very happy to have only 1/6th of them destroyed while he carries most of the remaining 5/6ths of the area population. This means that in fact, the management authority is likely to allow a higher proportion than 1/6th to be destroyed on individual properties, when distribution in the area is uneven. However, given good seasons and a period of some years before similar reductions are permitted, numbers should build up to the original levels again. In order to allow such a system to operate, the commercial shooter must accept a degree of mobility in his operations, moving from area to area throughout his allocated region over a period of several years before returning again.

A zoning scheme was introduced for commercial kangaroo shooting in New South Wales a year or two ago. The State has been divided into thirteen zones (Figure 1) each of which is allocated to a Licenced Fauna Dealer

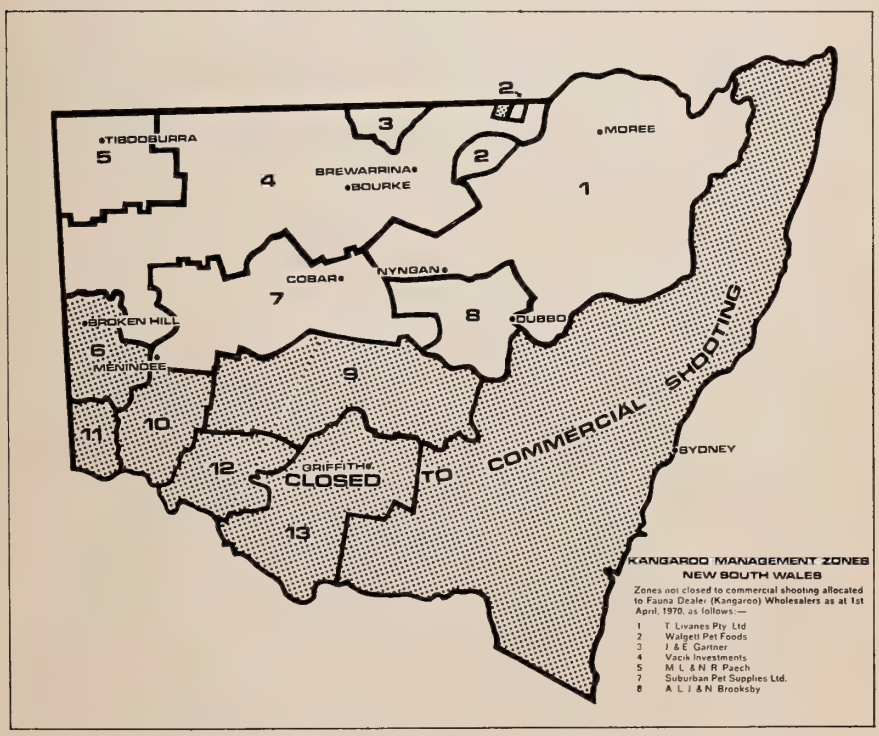

Figure 1.—Map of kangaroo management zones of New South Wales.

(Kangaroos). He may buy kangaroo carcases from Licenced Shooters (or Trappers) only in his zone. Within the zone, he may employ a number of shooters, or buy from independent shooters, each of whom may operate only within an allocated area. The number of shooters licenced has now been reduced to what is considered necessary to provide adequate shooting capacity for the level of cropping which is likely to be permitted in any particular zone and this is calculated from estimated population size and trends. Because of recent declines in population numbers resulting from dry seasons and over-harvesting in years gone by, a number of zones have been closed to commercial harvesting in recent years, and will not be reopened until population numbers warrant it. In addition, the whole of eastern New South Wales is closed to commercial shooting at any time, principally because the rough country and scattered populations of kangaroos make it impractical.

This zoning system and licence limitation have generally been accepted by the industry, although there have been local pressures for zone boundary adjustments or reallocation, and some illegal operations which have resulted in prosecutions. The graziers and farmers too, have generally found the system acceptable, as long as applications for licences to destroy pest kangaroos are dealt with promptly and there is a sufficient number of licenced trappers to ensure killing of the excess kangaroos within a short time. Some have objected to the centralized control as excessively bureaucratic, and tend to circumvent the system by ignoring it and culling the populations themselves. These problems are being tackled by the stationing of Service Rangers as Wildlife Management Officers in strategic centres to ensure rapid assessment and issuing of licences, and to assist in law enforcement and education.

Higher royalties per carcass and licence fees have recently been introduced throughout the system, in order to provide more funds for the employment of management staff and to encourage the better utilization of each legally taken carcass by the industry. New regulations will soon be introduced to provide for a system of tagging, which will ensure that the carcasses of kangaroos killed under licence are identifiable, and that the appropriate royalty has been paid. Tighter control over the import of kangaroo carcasses from other States will also restrict attempts to benefit illegally by the differences in regulations between neighbouring States.

The important aspect of this management system, which needs to be strongly emphasised, is that the destruction of kangaroos is not dictated by the needs or demands of the industry but by the need to afford relief to graziers and farmers who can show that they have an excessive number of kangaroos which are causing them economic loss.

What then is the level of cropping in New South Wales at the present time?

An analysis of applications and licences issued by the National Parks and Wildlife Service for the first four months of 1970 shows that graziers and farmers applied for licences to take 91,810 kangaroos, from a population estimated *by them* to be 292,845—that is, a cropping rate of about one-third. However, licences were granted by the Service during the period for the destruction of only 28,280 animals. Assuming that the estimates by graziers of population numbers are somewhat exaggerated, and that the number killed is not greatly different from that legally permitted, the total destruction for this period on these properties, appears to be not more than the 1/6th recommended by Winter.

It could be argued that there is a high incidence of illegal shooting of kangaroos, but against this must be placed the fact that there are also large numbers of kangaroos which are not the subject of licence applications—either because they live on parks, reserves or wildlife refuges, or because the property owners do not consider them to be a problem.

There is of course, a further problem which must eventually be faced if the Service is to achieve some sort of stability in kangaroo management. This is a calculation of the desirable frequency of kangaroos to be the mean level. Obviously cropping 1/6th of the population is only a means of maintaining a stable population size, but gives no clue as to what that population size should be. During good seasons, most graziers are happy to have a population of kangaroos of reasonable size on their land. During drought, this same number of kangaroos would be regarded as too numerous. From the resource manager's point of view, population levels need to be well above the minimal size for viability, but not so numerous as to be in pest proportions. A desirable level might be sufficient to ensure that kangaroos can be seen fairly easily by people travelling through the country and dispersed fairly evenly over a wide area, but not as abundant as to be in pest proportions. Just what that level of abundance is, no one knows. I do not know of any estimates of minimum viable population size—which could be given as a number of individuals in a single interbreeding population, or as a frequency of animals per square mile overall. Research on this problem is very desirable, though it might be very difficult to produce any meaningful figure. The Service has recently appointed a biologist and two assistants to commence the overall assessment of population levels and trends, and to attempt to determine a desirable level of abundance.

For the time being, we must use empirical methods, and will have to impose such controls as are necessary to maintain populations at levels which seem to us to be reasonable—and here the Service hopes that if it errs, it will be on the side of caution. Better too many kangaroos than none at all.

FUTURE POSSIBILITIES

Ultimately however, the approach to kangaroo management should change. Kangaroos are valuable animals which grow well in large areas of Australia and should be regarded by the man on the land as a resource and not a pest. This would involve two major policy shifts. First, there would need to be a change from ownership of all kangaroos by the Crown to some form of private ownership, or at least, to legal holding under licence as a stock animal. Secondly, the system of allowing destruction only when causing damage to rural properties would have to give way to an approved cropping of the legally held stock.

As has been mentioned by other contributors there are obvious practical difficulties in the first of these problems. Kangaroos are not easily retained on a property by normal stock fences, and they are not as yet identifiable from wild stock. Possibly, selective breeding and cultivation in captivity would lead to more docile animals which could be branded, rounded-up and transported to abattoirs quite easily but the techniques remain to be explored. Nevertheless, I believe that if these difficulties can be overcome, and kangaroos are managed by graziers as a stock animal, their survival will be as certain as that of sheep and cattle. It is wrong to say that they cannot be farmed. They are being produced by farmers now, and exploited by someone else! Why not by the farmer?

An incentive to such new management would be for kangaroo meat to be marketed for human consumption—thus raising the value of the crop—but until better methods of handling and killing the animals can be developed, the health authorities will not permit the sale of kangaroo meat.

All of these problems should be the subject of a research programme, and it is the hope of the National Parks and Wildlife Service that it can establish a research station in central-western New South Wales in the near future where, in conjunction with the C.S.I.R.O. Division of Wildlife Research, some of these problems can be studied.

If and when such techniques can be developed, there will still be a need for a shift in the basic philosophy of the man on the land. A survey conducted in 1968 by Mr. A. M. Fox revealed that, although graziers were

generally disturbed about the future of wool as a crop, and were seeking alternatives, a large majority considered kangaroos only as vermin to be destroyed. Indeed most would not accept any payment for animals taken off their properties, yet the same animals had been worth millions of dollars to the commercial kangaroo shooters who took them. Even in the present situation, where cropping of a wild population is occurring, it would be reasonable for the grazier to receive some return for animals which had eaten pasture on his land, and I believe that such a payment could be costed into the price of kangaroo by-products.

There is a further political problem to be solved in such an approach, and that is the attitude of the public. While no opinion poll has been taken, I think that most Australians, especially city dwellers, would not take easily to the idea of commercial cultivation and cropping of kangaroos. Australians are emotional about native animals, though they seldom attempt to rationalize their views and explain why it is considered morally wrong to crop kangaroos but morally right to crop sheep and cattle. As a biologist, I cannot accept the distinction, and believe that if it can be shown that the survival of kangaroos can be guaranteed by their commercial harvesting, then the idea will become acceptable.

There will, no doubt, always be a real pleasure for Australians in seeing kangaroos living wild and free, and this can be ensured by an adequate system of parks and reserves in appropriate areas of the State. However, the establishment of such a system is not a simple matter because of the intensive use of land for wheat growing and sheep and cattle raising in the areas where kangaroos are most abundant. By far the greater parts of the Central and Western Divisions of New South Wales are alienated for rural production. It is true that the Western Division of the State is largely Crown land under the control of the Western Lands Commission, but the system of perpetual lease is almost equivalent to freehold alienation. Some land remains in 99 year leases which are expiring during the next few years and reverting to the Crown. The Service hopes to acquire substantial areas of this land for park and reserve purposes, but there is also a strong demand for it to increase the holdings of some perpetual lease holders who believe that their areas are inadequate to provide a reasonable living.

The Service can, of course, buy up perpetual lease country on the open market, and it will, where necessary, do so. However, financial limitations make this less attractive than the taking over of expiring leases. Even so, there is considerable opposition from some sections of the grazing community to the spread of the park and reserve system in these Western Lands because of a belief in the righteousness of rural settlement and production along traditional lines. While I can understand the emotional attachment of man to a productive landscape, I cannot accept that it always has a rational basis in terms of low cost—high benefit to the community overall or that the conservation of an adequate system of parks and reserves, and of our native wildlife, has any less righteousness.

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CONSERVATION AS A CO-OPERATIVE PROCESS

by J. K. DEMPSTER

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In the final session of the symposium entitled 'Conservation of Kangaroos' we encounter the familiar difficulty that 'Conservation' is open to so many shades of interpretation that almost anyone is able to choose a meaning to which he can subscribe without compromising his established attitudes.

Many definitions of conservation are possible, but one which is brief and to the point describes it as "the wise use of resources". Of course we must insist that wisdom should be based on knowledge. Everything that has been discussed in the symposium today is pertinent to the conservation of kangaroos. The more we know about the evolutionary history and the diversity of our fauna, and the changes which it has undergone in modern times; the more we know about its ecological needs, and (note the full implication of the definition) the more we know about its value to us, whether as an economic resource or as a cultural or recreational asset, the better will we be able to make wise judgements as to how it should best be conserved. Of course our knowledge can never be complete and so our judgements must always be made in the light of what information we have, and with an awareness of what still remains unknown.

Judith Wright has recently expressed* with remarkable clarity and force, the quite indispensable role which informed and involved members of the public can play in providing much of the sheer effort required to initiate and sustain many of the processes of conservation. These are the people whom I suppose we must call the lay conservationists.

The scientists and technologists ("professional conservationists", if you like), so often seem to the laymen to be rather cold fish. They are trained to be suspicious of lines of action which have not been arrived at by way of thoroughly rational argument. The professionals feel that their own work may be suspect if they are known to be too closely involved with those who, quite frankly, are moved by what Judith Wright lists as 'concern', 'distress' and 'love'.

Governments, for their part, seem to be intrinsically refractory, cumbrous and inert.

There is much truth in all of this. We know only too well of the distrust that often exists between many lay organizations and professional conservationists. We know that scientists are often hopelessly inept at conveying their ideas to lay people and governments. We know that even when politicians call for scientific advice, they are often less influenced by its rationale than by its implicit popularity or cost.

Now, having the problem presented to us in these terms enables us to recognize one of the greatest hindrances to the effective progress of nature conservation in Australia at the present time.

There are at least three quite clearly identifiable groups within the community, each of which could play a fundamental role in achieving some progress in conservation. Yet each has such a profound lack of understanding of the other two and the distinctive roles which they should play, that any co-operation between them is kept down to an absolute minimum. Perhaps

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* Wright, Judith, "Conservation as an emerging concept"—*Occasional Publication, No. 2,* Australian Conservation Foundation, Melbourne, 1970.

worse still, the members of these groups, for the most part, seem to be quite unaware that their own respective roles are different and distinctive and limited. We are losing not only the opportunity for the actions of these three groups to reinforce one another, but we are dissipating the endeavour of each group to fulfil its own specialized function.

We have generally failed to recognize that the processes working for conservation must be managed to constitute a properly ordered and integrated system.

Analogies are never entirely satisfactory but it may help to compare these conservation processes with a mechanical system, let us say a motor-car. The system needs a source of energy to get it moving and to keep it moving—it needs to be continually refuelled, and I suggest that it is the distinctive task of those whose involvement with conservation stems primarily from concern and love to provide that energy and overcome the inertia of governments.

Politicians need to be continually alerted and made aware that the whole subject of conservation is one of urgent concern to the public, and this task of energising the system is one for which professional conservationists are generally unsuited because of their pragmatism and relationship to government.

If the available energy is to be used efficiently, a properly designed and properly maintained mechanism must be provided. It is the distinctive task of governments to see that a well designed structure of legislation, law enforcement, education and technology is established, sufficiently adaptable to meet the needs of conservation as they arise.

Finally, if governments are moved to act, and if the motion is going to mean progress, then the system must be given direction. The task of steering the system is the distinctive obligation of conservation scientists and technologists.

The Australian community has not yet developed its commitment to conservation sufficiently for such a system to have evolved, and nowhere are mistakes more imminent as a result of this lack, than in the business of kangaroo conservation.

For some years past, amateur organizations and individuals concerned about kangaroos have become more and more disturbed by such confused reports as were available to them, relating to the status of various species, methods of control, and the emergence of the meat and skin industry. Part of the trouble is that there are still insufficient facts on which completely objective management programmes can be based; but even those facts which have been accumulated by research workers have not been adequately interpreted for the information of lay conservationists, to earn their confidence in any management procedures which might have been implemented.

In this situation the amateurs, having overcome some of the inertia of governments, are impatient with the professionals for their unreadiness to take advantage of the opportunity. It is not surprising that they are now urging on governments some of their own suggestions for protecting kangaroos from over-exploitation, and thus they are taking on a steering function for which they are not equipped.

There is some evidence now that several governments in Australia are becoming alerted (and perhaps even alarmed) by the popular outcry about kangaroo conservation, and they are seeking around for an answer. But for quite a long time now Australian museums have been regarded by governments as little more than traditional financial burdens, and fauna conservation departments as rather new fangled luxuries, so that scientific answers to such questions are not easily obtained. On the other hand the answers proffered by amateur conservationists often have a certain compelling simplicity and breadth of vision which governments may find appealing, particularly when their potential cost is compared to the alternatives put up by academics (see "Proposal to Establish a Biological Survey of Australia", *Aust. J. Sci.*, Vol. 31, No. 11).

Unfortunately it is far from certain that these attractively simple answers are really related to the basic problems. Most of the proposals are only extensions of the protection laws which have formed the basis of our fauna legislation for the past 60 or 70 years, while a dozen species of kangaroos have come to the verge of extinction. There are suggestions that such laws should now be applied on an Australia-wide basis, either by agreement on uniformity between the States, or by some device such as the imposition of an export ban on meat and skins at Commonwealth level. Such proposals ignore the complexity of the problems associated with kangaroo management, and the fact that these problems may differ so fundamentally from place to place and from time to time. Protection is a useful tool which must always be available to the conservationist, but it is not the easy way out of every conservation problem, and it may at times be a hindrance to the implementation of some rational conservation projects.

The suggestions may seem harmless enough in themselves, but unless there are sufficient individual politicians, who have some knowledge about the complexity of wildlife problems, governments, acting corporately, may find in them a convenient way of diverting attention from conservation's more urgent and expensive needs which include education, land reservation, ecological research, management of animal populations, the stabilization of exploitive industries and (in the case of kangaroos) effective pest control.

The progress of conservation in Australia cannot be expected to proceed in any rational way without far more effective liaison between those groups most intimately concerned with its success.

A comparison may be drawn with agriculture where the need has long been recognized to maintain close co-operation between governments, a group of involved non-technical people, and the professional researchers and technologists. Extension, education and liaison are recognized as an indispensable and major part of the functioning agricultural system. Yet no wildlife conservation service in Australia has trained staff to discharge this seemingly fundamental task.

Fortunately my analogy between the function of the conservation process and a mechanical system is inexact. There are many people concerned with conservation who cannot be conveniently allocated to one part of the system or another. They are the educators on whom we have relied in the past. There are lay naturalists who take the trouble against all odds to find out what the professionals are doing, and communicate this to their fellows. Some even manage to convey to an occasional politician or professional a sense of 'concern' and 'love'. There are politicians who recognize that problems of this nature are not to be solved in the lifetime of a government and that they require careful long-term planning, rather than expedient and facile answers. There are even professionals who are not content to practice their trade in seclusion but endeavour to make their discoveries and plans available and intelligible to those who are ultimately concerned. Such people have played an important part in the evolution of Australian conservation thinking, and will continue to exert a most important influence on it, but they are too few in number to be regarded as a permanent substitute for a professionally trained extension and liaison service.

It may be at the present time, when all governments profess an increasing concern for wildlife conservation, but when there are special difficulties in defining the complementary roles of Commonwealth and State, that the establishment of a conservation education and extension service, supported by Commonwealth funds and working within the structure of state conservation agencies, might be one avenue by which the Federal Government could make a significant contribution to the emergence of a co-operative conservation process within the Australian community.

SUMMARY

by R. STRAHAN
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STRAHAN: Directly or indirectly, all of us in this symposium have been concerned with the question of extinction of kangaroos. Extinction of species is a necessary component of the evolutionary process and, in a successful group of animals there is a high rate of turnover of species. The evolutionary radiation of the macropods was marked by such extinction and replacement but one must assume that, from the Tertiary to the Pleistocene, there was nevertheless an overall increase in the number and diversity of species. Then, in the Pleistocene, we find a relatively sudden (and 'dead-end') extinction of larger macropods and other marsupials. Dr. Ride has suggested that this removal of larger species is related to the advent of pre-industrial man and possibly to his use of fire. Certainly, there is suggestive evidence of this from Western Australian studies, and also from other continents where the arrival of man marked the onset of what has been called the "Pleistocene over-kill".

With the arrival of industrial man in the 19th Century a new wave of extinctions began, this time leading to the disappearance of smaller macropods. Many factors have operated against them, but the most significant is surely the destruction or simplification of their habitats. As Mr. Calaby has shown, many of the surviving species are extremely vulnerable, and their vulnerability must increase with increased human demands upon land for farming, forestry, mining, and housing. It is unfortunate, perhaps ironic, that present public concern tends to concentrate on the large grey and red kangaroos, whose numbers have increased due to human activities, while little attention is directed towards some of the acutely endangered wallabies.

Dr. Newsome's detailed study of one species in one area, gives us a clear picture of a population in a delicate relationship with a harsh climate. He has demonstrated the drastic change in population structure brought about by drought, and his findings point towards a strategy of cropping, a subject to which many speakers have reverted.

Dr. McDougall's description of the situation in Queensland leaves me somewhat confused. Certainly it would seem that the sustained harvest of about a million kangaroos a year is not indicative of a falling population. We are assured that the situation is stable, yet the fact that Queensland has embarked on a new strategy of separating chillers suggests that all is not well. There would seem, too, to be room for doubt regarding the effectiveness of control of chillers without concurrent control of shooters. Perhaps all is well, but we do not yet have the sort of information that will satisfy conservationists.

The kangaroo meat industry is relatively new. Killing for skins is long-established but this was a seasonal activity based on individual, low-capital effort and, for obvious reasons, smaller animals were not taken. The exploitation of kangaroos for meat is related to the introduction of myxomatosis, a rapid decline in rabbit populations, and the consequent collapse of the chilled rabbit industry. The shift from rabbits to kangaroos was rapid and unpremeditated and we were suddenly faced with a large vested semi-industrial interest in predation upon kangaroos.

The initial success of the kangaroo meat export market led, not to a mere stabilisation of the old rabbit chillers, but to an expansion of the industry on a get-rich-quick basis and, even now, most of the operators are concerned with short-term gains rather than the long-term maintenance of a resource.

The situation has been considerably confused by conflicting motivations. In general, State and Federal Governments have given overall protection to marsupials, including kangaroos, and permission to shoot or trap them has usually been restricted to times and places where they are designated as pests. I think that we all agree that kangaroos can be pests, but it is confusing for an animal to be shuffled between two exclusive categories, 'protected' or 'pest', with no half-way house. The situation is further complicated when money can be made by exploiting 'pests' and I suspect that there has been a

great deal of provocation one the part of interested parties to have kangaroo populations declared to be pests so that they may then be shot for profit. I find a parallel in the situation in respect of the wombat in Victoria: when there was a bounty on it, it was shot with enthusiasm, but since the bounty has been removed far fewer farmers seem to be concerned about its pest-potential.

Mr. Doohan's excellent, low-key contribution left us with no doubt that kangaroos can be pests on grazing properties, and such serious pests on farming properties that coexistence may be impossible. I feel that he attached undue weight to competition for water, fouling, trampling, and damage to fences, but his comments on competition for pasture may give us pause for thought. He has said that kangaroos take the best food and that they take it before the sheep can get to it. If this be the case the results of research on dietary differences is open to the interpretation that sheep have different stomach contents from kangaroos because kangaroos get in first. This point should be borne in mind in future studies.

Although Mr. Livanes drifted from his subject to complain of the attitudes of non-users of kangaroo meat, he spoke with considerable authority. There is no reason to doubt that, under normal conditions, kangaroo populations should provide a potential surplus that could be cropped. He maintains that, if there is a resource that can be utilised, it makes economic sense to utilise it, and in such a way that the resource is maintained indefinitely. We have ample evidence from North America and Africa that wild populations can be cropped, often to the benefit of the population.

However, I do not believe that it is proper for the person with a vested interest in killing kangaroos to say more than that he is doing it for a profit. To say that he is helping the species or is removing pests is to trespass in areas where his motivation can reasonably be suspected. I know of no exploitative industry where there is not sustained pressure from the exploiters for higher and higher yields, and it is necessary for government agencies to impose restraints.

Mr. Livanes complains that his industry receives little government support: I am sure that he must realise that it is a hot potato. Governments are prepared to permit the taking of kangaroos designated as pests and they are usually prepared to put limits on the kill, but they are not prepared to go out of the way to assist shooters. It is not a 'respectable' industry and, as Vincent Serventy has observed, governments are responsive to the cries of an outraged public.

If the kangaroo meat industry is to survive—and perhaps even to become respectable—it certainly must come under the sorts of constraint that Livanes recommends, with control of chillers and shooters and careful monitoring of populations. It is clear that he himself is concerned to maintain the resource that he is exploiting, but the same cannot be said for many others in the industry. We have witnessed catastrophic variations in kangaroo populations in several states, to the point that C.S.I.R.O. issued a warning a few years ago that a continuation of the then current shooting pressure, particularly in times of drought, could seriously endanger the red kangaroo. The sad fact is that the kangaroo meat industry is not planned, is not self-disciplined, and is probably too large.

From time to time it is suggested that kangaroos should be farmed. Professor Sharman has thrown cold water on this idea by drawing attention to the rate of growth of kangaroos in comparison with sheep. Even though the carcase of a kangaroo includes a far higher proportion of meat than that of a sheep, the amount of food consumed by a kangaroo to produce a pound of edible flesh is far greater than a sheep needs to do the same job.

On the other hand, kangaroos are better adapted to Australian conditions than sheep and could perhaps form the basis of a more efficient meat industry in arid lands. There remain, of course, many problems of domestication, without which we are left with extreme difficulties in herding the animals

and bringing them to centres where they could be slaughtered under humane and hygienic conditions.

Personally, I believe that kangaroo meat is only of commercial interest because it is cheap. The moment we begin to treat a kangaroo as an animal to be farmed and put effort into its husbandry, we shall find that the game is not worth the candle. Of course, if kangaroos were really rare, we could probably make kangaroo tail soup a luxury item like caviar!

Whether or not Mr. Serventy is a man-in-the-street (whether anyone is?), he presented that man's view forcibly. It was brought home to the organisers, when we had to turn scores of people away from this symposium, that a large segment of the population feels disquiet, a lack of confidence in governments and wildlife administration, and that something needs to be done. To use a current Americanism, we have a credibility gap between the professionals and the people.

Quite rightly, he points out that there is room for, and need for, emotion in our attitude to wildlife conservation, but it is possible that a lack of public confidence in the professionals may lead governments to panic. In this respect it is pleasant and reassuring to note that four of the seven members of the House of Representatives' Select Committee on Wildlife Conservation are in the audience.

Serventy's remarks regarding the potential value of the tourist and outdoor recreation industries and the place of wildlife in these are very pertinent. Although hard-headed businessmen tend to decry wildlife conservation as a luxury set aside for a minority of nature-lovers and scientists, harder-headed and more far-sighted captains of commerce may well realise that the preservation of wildlife over large areas could be a very profitable national investment. With the likelihood of diminishing returns from sheep and wheat, we would be wise to consider now whether national interests would not be better served by the reversion of some farm and grazing lands to vast faunal reserves. Certainly, any case for further agricultural encroachment on relatively untouched land would require very compelling arguments (far better, for example than were brought forward in the recent case of the Little Desert in Victoria).

In speaking for the National Parks and Wildlife Service of N.S.W., Dr. McMichael put forward two postulates that are hard to refute: first, that kangaroos can be pests; second, that if such pests are to be destroyed, it is ridiculous not to utilise them commercially—irrespective of whether this requires a large or a small industry. This involves a wildlife authority in deciding when and where kangaroos are in pest proportions, and how many need to be removed to relieve the farmer or grazier without endangering the survival or unduly restricting the range of the species. Without criticism of any Australian wildlife authority, it must be said that we have not yet enough information to make such decisions with confidence.

The city public, the men on the land, and now the kangaroo shooters say that something must be done. Academics say, truthfully, that they do not know enough to lay down a quantitative policy but, despite this, the wildlife administrator has to tackle the problem. I do not believe that it is being tackled better in Australia than by the service directed by McMichael. The N.P.W.S. is a relatively new organisation and was funded and staffed just in time to control a situation that was becoming acute, but it has established a policy which should satisfy all responsible segments of the community. (I would mention, parenthetically that, as a wildlife service, its first responsibility is to preserve fauna: its motivation is therefore different from those of faunal authorities which come under State departments of agriculture, or other exploitative industries).

However inaccurately, the N.P.W.S. has set out to estimate the populations of large kangaroos in New South Wales and, however inadequately, to determine a pattern of pest control and cropping. Winter's extremely theoretical calculation that kangaroo populations can withstand a cropping rate of one in six per year

has been accepted as a guide but permission has been given for an annual removal of no more than one kangaroo in ten in New South Wales. The method of monitoring killing by the issue of carcass tags promises to make these controls effective.

Yet the farmer whose crops are being trampled, or the grazier who is running more sheep than kangaroos, is not going to be satisfied by a policy of cropping that leaves the same number of kangaroos on his property. Nor is the nature-lover going to be pleased—if he already believes that there are too few kangaroos in certain areas—that the annual removal of one in ten will not adversely affect the population.

A balanced policy of kangaroo conservation must involve a redistribution of existing populations—severely limiting these where they seriously affect industries of national importance and providing for populations of optimum density in a large number of accessible places of immense area which are devoted to the prime purpose of faunal conservation. Such areas, which for the sake of convenience, I shall call National Parks, must include not only facilities for non-destructive public recreation but also enclaves from which all but specifically authorised persons are excluded.

There are not enough of such areas and, as McMichael points out, they must be obtained within the next few years if we are not to be too late. It is said that there is difficulty in obtaining such land, but I would regard this as the least of problems facing us. Crown land can be dedicated by government and freehold or leasehold land can be acquired by purchase. If we began to talk in millions of dollars instead of tens of thousands, we could set aside a 5% sample of Australia as national parks, almost overnight.

It has been said that a learned symposium is an occasion when well-known authorities present their well-known papers. To some extent this is true of the present gathering. Every zoologist gathered here has given a rather predictable discourse, the substance of which was well known to his colleagues. But perhaps it has been helpful to arrange a confrontation between them and representatives of other segments of society whose interests in kangaroos have different emphases. Our function is not complete for, despite a surprising level of agreement on principles, we find ourselves sadly lacking in detailed knowledge. Nor is our function restricted to communication among the 130 people gathered in this room: the publication of these proceedings and their accessibility to thousands of interested people outside this room will be of far greater significance. Although it is not my function as rapporteur to do so, as one of the organising secretaries I wish personally to thank all contributors who, at very short notice and at some personal inconvenience, have come together today to discuss the interactions of two interesting groups of animals: kangaroos and men.

DEMPSTER: Thank you, Mr. Strahan. To be able to bring together a whole day's work like that is a feat of no mean skill. We thank you for it. I hand over to Mr. Smail.

SMAIL: Ladies and Gentlemen, just before we close it is my pleasant function to ask Dr. F. H. Talbot, Director of the Australian Museum, to take over the microphone and just formally say "Thanks" to our contributors and such other remarks as he may feel necessary.

TALBOT: I think I can do it one minute: and I am sure that all of us are keen to get off these hard seats and perhaps start talking about what we've been listening to. I don't really think that the task I have been given to perform is a necessary one—I think by your applause you have thanked the contributors, and also by your attention. The Symposium is now over. We go home feeling sometimes, perhaps a little flat—perhaps a little argumentative—and one wonders what in fact we have gained. What did the Symposium achieve? Now, some of the benefits are obvious, I think. I have learnt facts that I did not know in spite of being a biologist and having heard some of the speakers before. I learnt facts not only from the scientists

but from our other representatives from the grazing industry. I think we've all done the same. All of you have learnt something, whether you be scientists, graziers, industrialists, parliamentarians or laymen. The other benefits of this Symposium flow later. I think there will be increased sympathy between us—sympathy through the understanding we've managed to get through this Symposium without getting overly excited, and we've used our minds and not solely our emotions, although emotions are vital in the conservation battle and they're important to all of us. One would hope to see flowing from this increased sympathy that in future we would have a little more understanding of the other man's point of view: and that in any attempts at rationalising our resources, whether for industrial use or for tourism or purely because we like kangaroos, we are going to have to have to make compromises. I think this Symposium will go far to achieving this and it may then result in better decisions and a better chance to keep the kangaroo functioning as an integral part of the Australian scene.

Now, first, I'd like to thank the people who organised this—and I speak her not as a Councillor of the Zoological Society but as one of the people in the Symposium. We must thank the President of the Zoological Society for organising this for us. We must thank Luv Petfoods who provided the funds necessary to get the people here: and we've had people who are the top people in their fields and we are very grateful to Luv Petfoods for this. And, finally, we must thank the contributors. Mr. Strahan has done so already—they have given up time and helped us learn something more. And I also hope that even the contributors have learnt something from the Symposium. So I would now turn back to the Chairman and ask you to express your thanks to those who made this Symposium possible.

SMAIL: Well, Ladies and Gentlemen, if I may say so without sacrilege—go, it is finished.

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